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NATURAL CONSTRAINTS ON LIVESTOCK PRODUCTION IN THE TROPICS AND SUBTROPICS: IN REFERENCE TO AFRICA

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INTRODUCTION

This article discuss, briefly, the natural constraints imposed on livestock production by climatic elements in tropical and subtropical zones. The climatic elements anywhere have direct and indirect impacts on thriveness and productive efficiency of livestock species and breeds. Particular review on the direct effect is conferred on heat stress, as generally encountered in these zones due to high temperature and intensive solar radiation. The discussion of the indirect effect is concentrated on the precipitation (rain fall) level as a determinant of the availability and quality of the vegetative feed resources for the different types of livestock, alongside arid conditions and drought cases. A brief reference is given to the climate factor in the spread of parasites and endemic and epidemic diseases.

The treatise is concerned, in particular, with African conditions, Africa extends exactly in the Tropics and subtropics isolated from the Temperate zone.

In the majority of African countries, mostly, all livestock production sector has significant participation in the family income and in national economic return. This role is more evident in counties with extensive rangeland and nomadic system of rearing. Development of this sector can be, has to be ,achieved by dual integrated approaches, national general strategy and private schemes. The success of these approaches relies on: 1) Comprehensive collection of basic information on livestock status (species, breeds and density, reproductivity, productive efficiency and adaptability to natural conditions; climate, vegetation, parasitic and endemic diseases...etc.) in each geographical region in the same country. 2) Distinctive study of the social characteristics and economic capability of the citizens in each region is a must for their cooperation with and incorporation in the regional plans.

Elements of Natural Constraints

The natural constraints in Africa stem from both geographical location and topographical structure. These two features impose particular regional climatic conditions, consequently types of vegetation complexes reflected on nutritional resources. On the other hand that climatic conditions activate parasites infestation and endemic diseases.

Africa occupies exactly Tropical and Subtropical zones (from latitude 34°S to 37°N). The topographical structure varies regionally; the high mountains in the eastern side and north-west region, central and south Africa plateau, deserts and rivers' valleys.

This geography-topography status determines, inevitably, tile climatic conditions as regionally characterized. Williamson and Payne (1988) summarized climatic conditions as follows. "Climate of elements that include temperature, humidity, rainfall, air movement, radiative conditions, barometric pressure and ionization. Of these, temperature and rainfall are the most important. In practice, effective rainfall, that is the amount ultimately available to the vegetation, is more important index than total rainfall. Many attempts have been made to classify climates, the best-known classifications being those of KÖeppen (1931) and Thornthwaite (1948). Holdridge (1967) proposed a "Life zone Ecology" classification combining latitude, altitude, rainfall and mean temperatures that is particularly useful for agriculturists. A simple classification is that proposed by the United States Department of Agriculture (USDA 1941). In this system climate in the tropics is classified into the following categories: equatorial or super-humid, humid, sub-humid, semi-arid and arid. It has been found that there is a close relationship between these climatic zones and the major vegetation climax types and soils". The map in figure (1) shows the agro-bioclimatic zones in Africa.

Temperature, humidity, precipitation (density of rainfall) and insulation (density of solar radiation) are the most determinant climatic elements, alongside day light intensity and duration, barometric pressure and air movements. Figure (2) shows the general temperature isotherms of Africa in January and July. The temperature decreases with increased altitude (Fig.3). Solar radiation is intense in Africa (Fig.4), as tropical and subtropical zones compared to the temperate zone (Table 1). Figure (5) depicts the regional rainfall level allover Africa, the level is a product of latitude (Fig. 6) however affected by altitude (Fig. 7) and sea shore. These climatic elements impose constraints on livestock thriveness and productivity either directly or indirectly (Fig. 8), The direct effect is imposed on the animals' physiological reactions and biological performance. The indirect effect ensues through the availability of vegetative sources for animal nutrition, particularly in rangelands, alongside the cultivated fodder crops and byproducts. (Fig. 9) shows the regional distribution of plant associations (Vegetation types) in Africa denoting the substantial circumstances for livestock nutritional resources. Another indirect effect

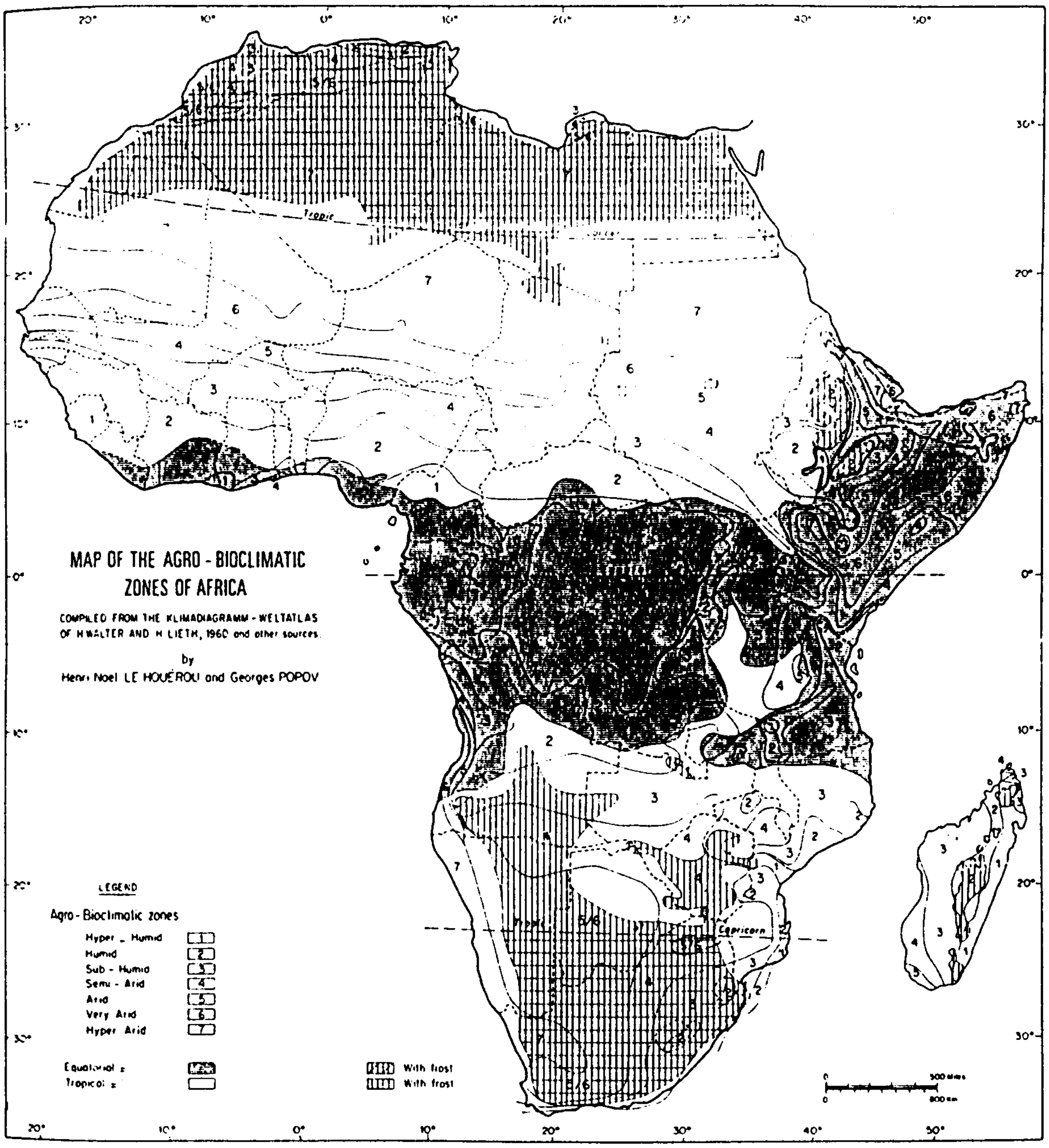


Fig.1: Agro-bioclimatic zones of Africa (Le Houerou et al., 1993).

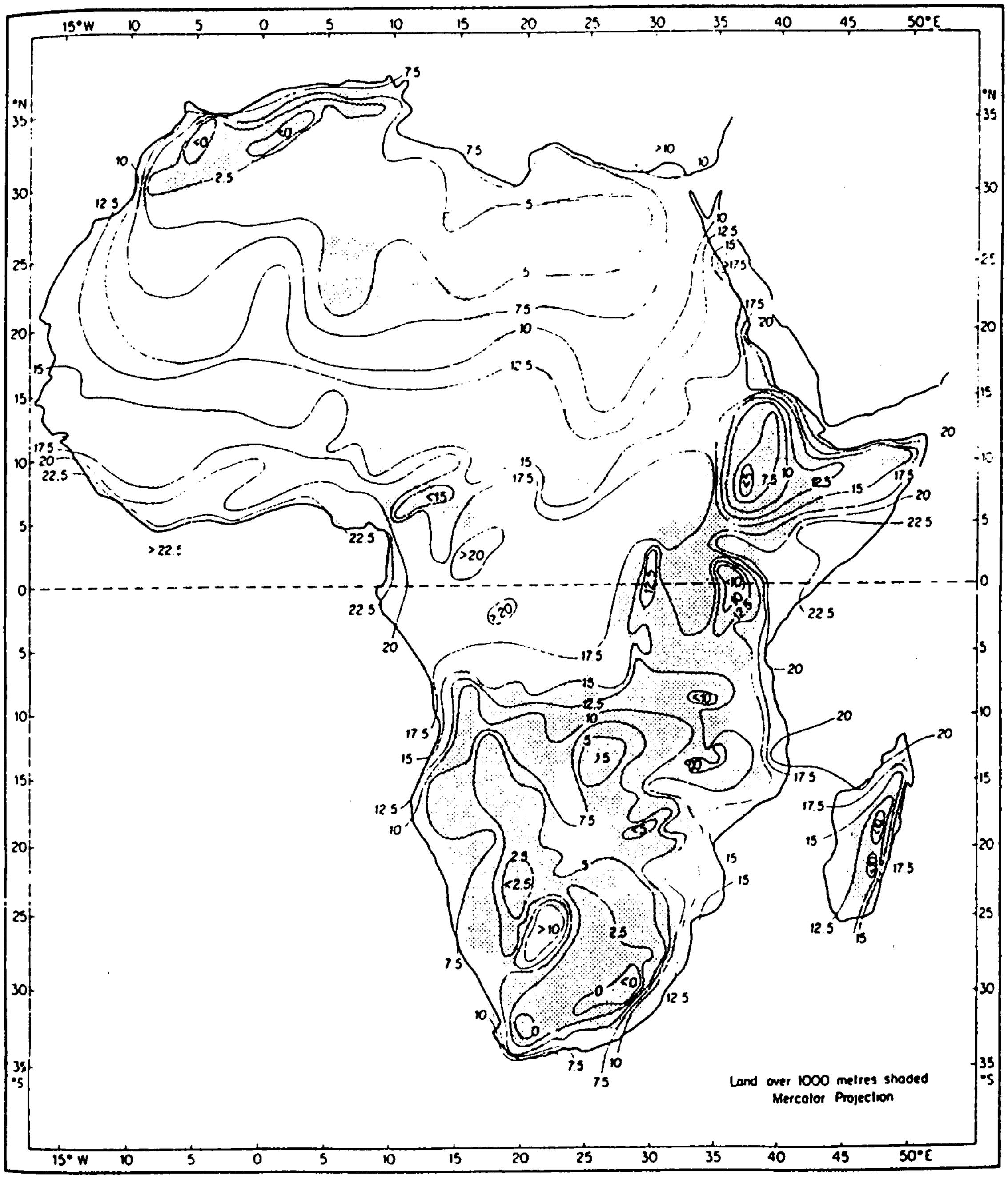


Fig. 2: Temperature during January and July in Africa (Willett et al., Philips Modern School Atlas 1983).

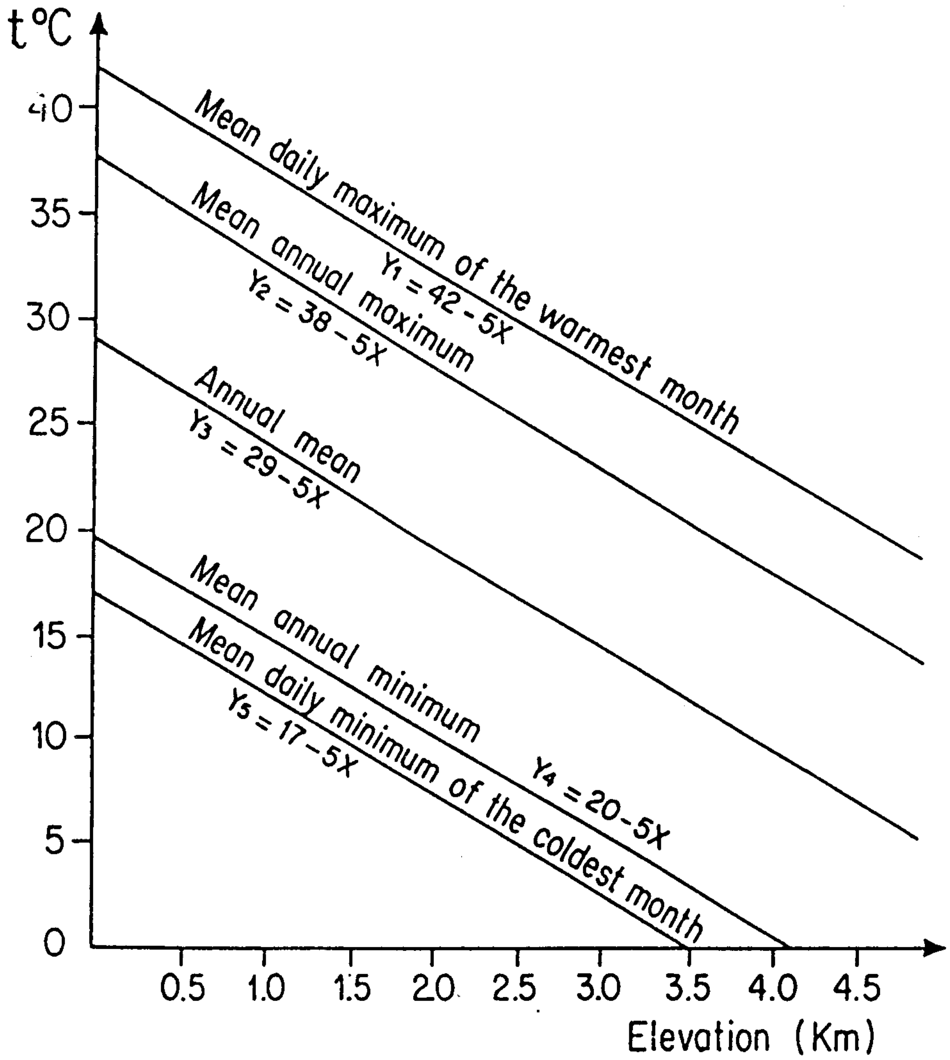


Fig. 3: Change in climatic temperature with the altitude: temperature (t ° C) in Ethiopia at elevation from the sea level (after Le Houerou, 1984; from Le Houerou et al., 1993).

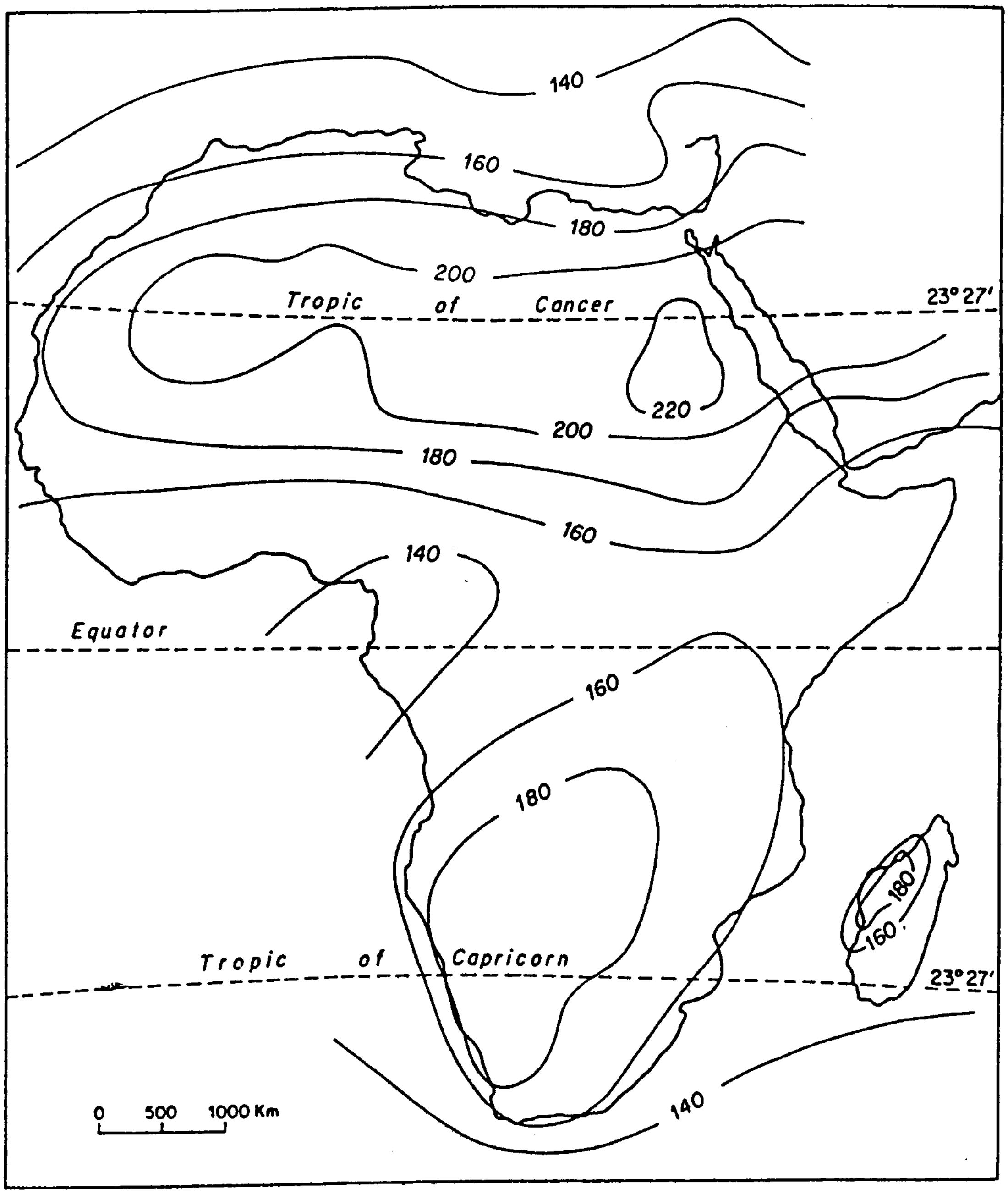


Fig. 4: Radiation energy in Africa, (Kcal cm^{-2} Yr^{-1}) (after Landsberg et al., 1965; from Le Houerou et al., 1993).

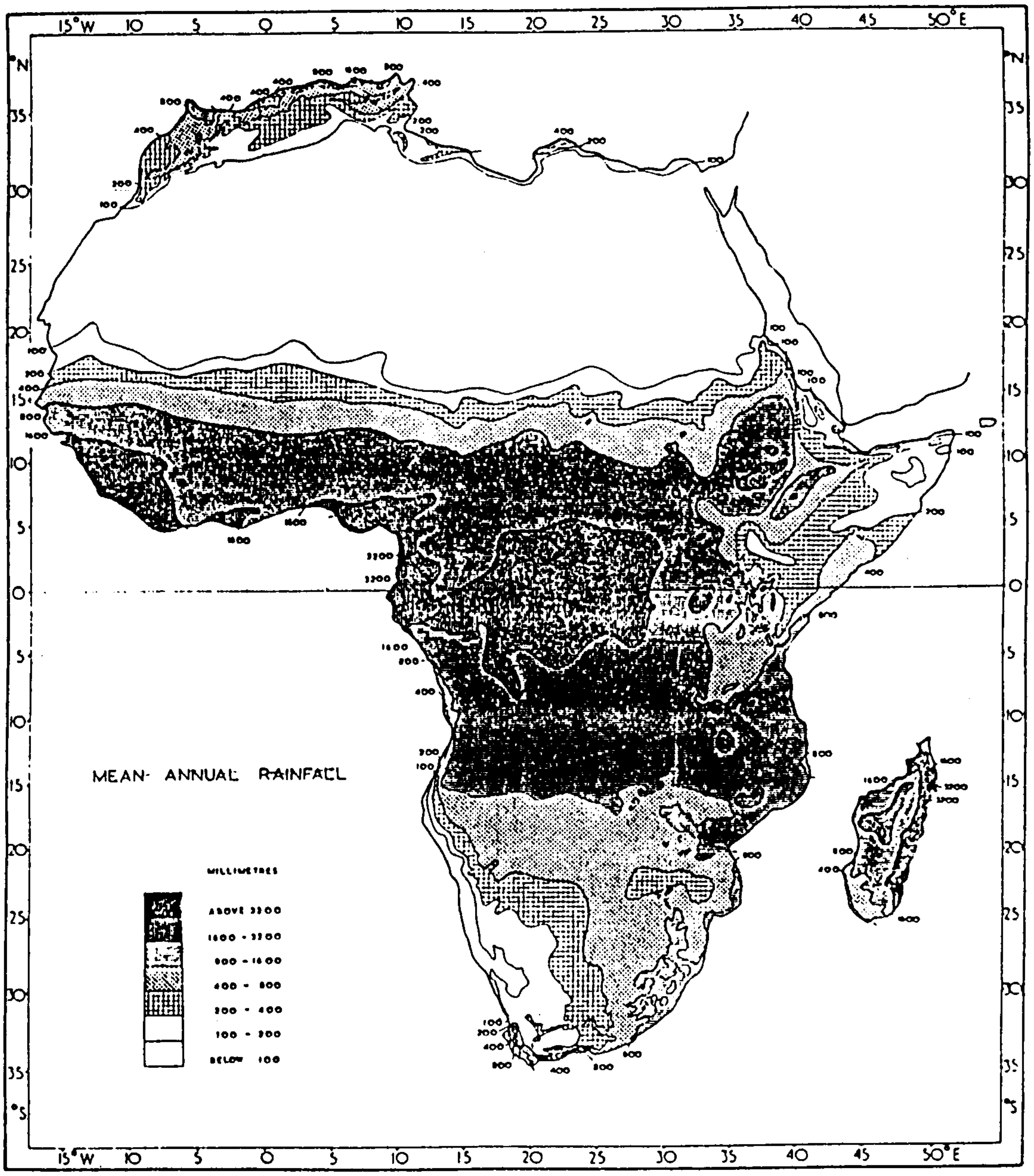


Fig. 5: Mean annual rainfall in Africa (after Thompson et al., 1965; from Le Houerou et al., 1993).

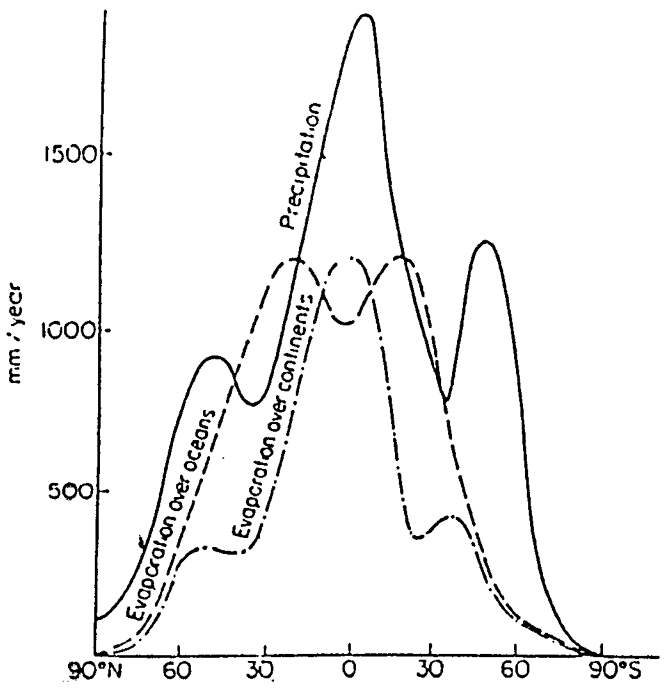


Fig. 6: The average annual rainfall (precipitation) with Latitude, alongside evaproation (after Sellars, 1965; from Bradshaw, 1979).

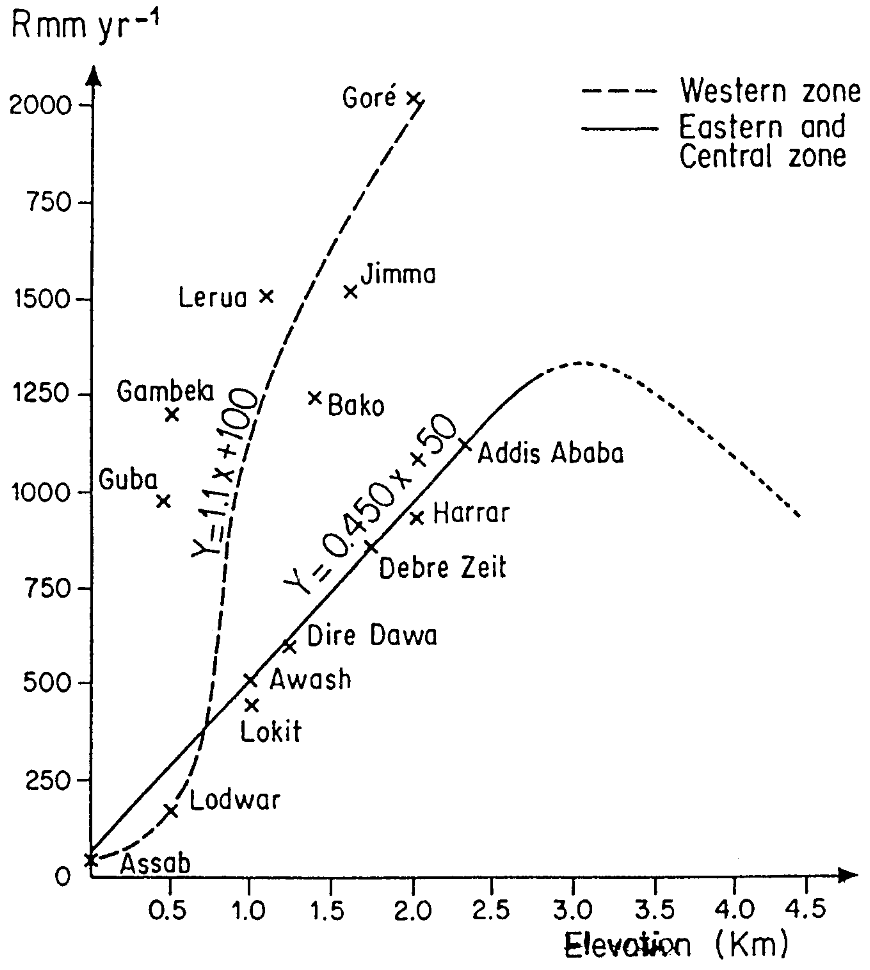


Fig. 7: The average annual rainfall with altitude, in Ethiopia (after Le Houerou, 1984; from Le Houerou et al., 1993).

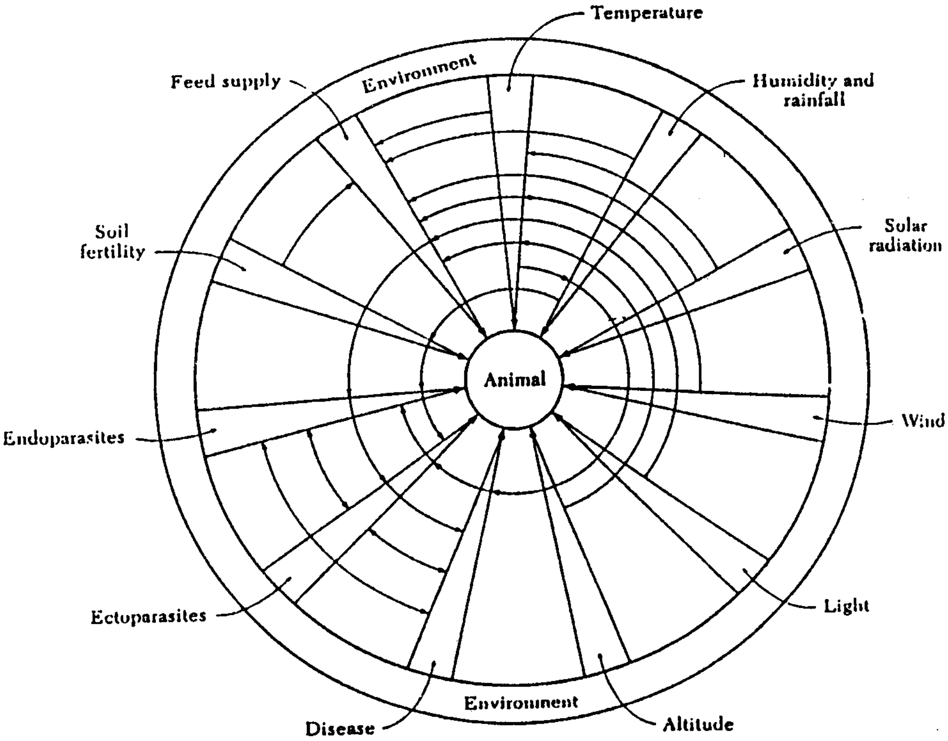
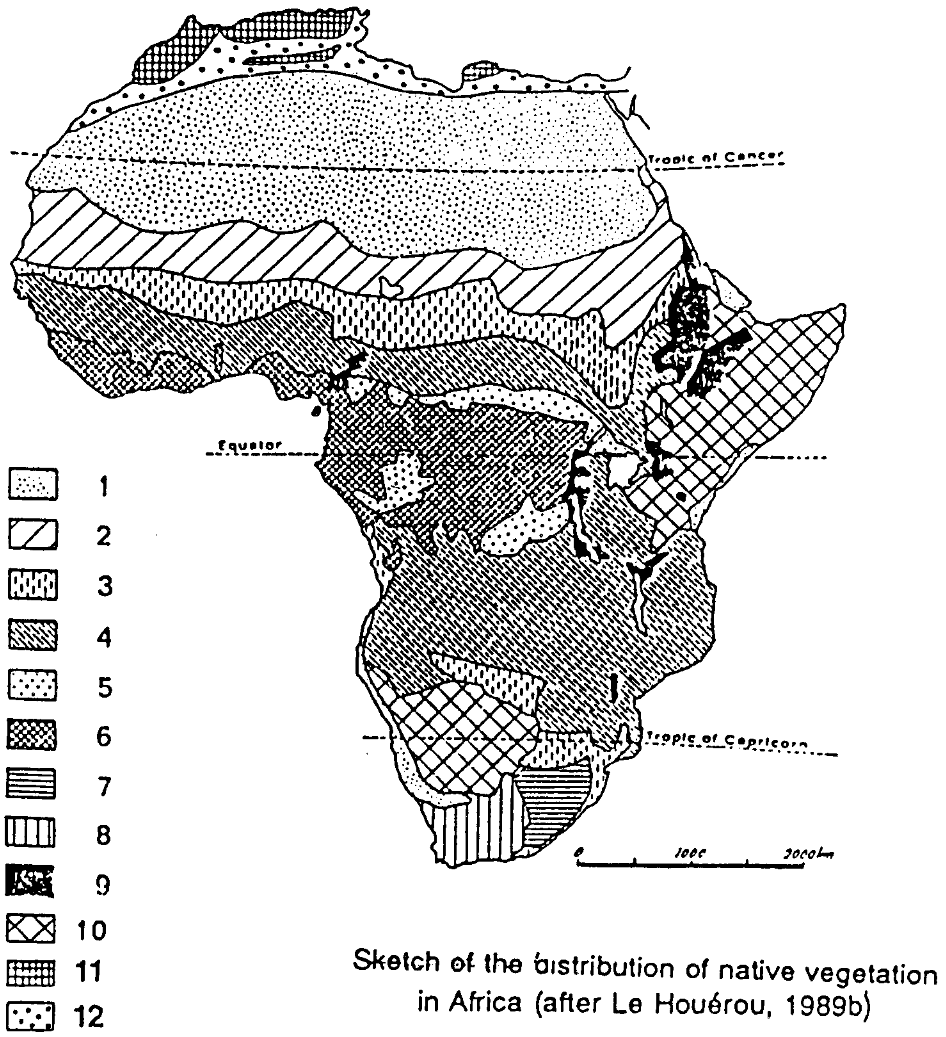


Fig. 8: Environmental factors having direct and/or indirect effects on animal performance (after Mc Dowell, 1967).



1 = Desert
2 = Sahel - *Mimosoideae* Scrub and *Combretaceae* Savanna
3 = Northern Sudanian Savanna
4 = Southern Sudanian Savanna and Miombo Savanna-Woodland
5 = Mixed Forest, Woodland and Savanha
6 = Guinean and Congolian Rain-Forest
7 = Sub-Tropical and Temperate Grassland
8 = Mixed Shrubland and Grassland, Dwarf Shrubland
9 = Montane and Afro-Alpine mixed formations
10 = *Acacia-Commiphora* Scrub with Perennial Grasses (Eastern Africa and the Kalahari)
11 = Sclerophyllous and Acicular Mediterranean Forest and Shrubland
12 = Perennial Grass and Dwarf Shrub Mediterranean Steppe

Fig. 9: Natural plant – associations (Vegetation types) in Africa. (from Le Hourou et al., 1993).

is brought about by intensifying parasites infestation, endemic and epidemic diseases, in particular by parasites vectors of diseases, such as ticks/piroplasmosis and Tsetse flies/Trypanosomiasis.

Table 1. Solar radiation energy in different climatic zones (from Webster and Wilson, 1980)

Zone	Total input of radiation Energy (kcal cm^2/year)	Seasonal variation in radiationl input (cal cm^2/day)		Potential dry matter Production from 3% Conversion of light Energy (ha/year)
		Winter	Summer	
Wet tropical	130 -160	360 - 420	300 - 510	41 -51
Subtrobical	145- 170	180 - 290	510 - 580	46 - 54
Temperate	84 - 115	50 - 120	410 - 470	27 - 37

Direct Effect of Climate on Livestock:

Physiological reactions

The direct effect of Tropical and Subtropical climate, on animals' physiological reactions and biological performance, occurs, mainly, in accordance with Input - Output of radiative energy (thermal energy) and /or moisture, from air and surrounding objects (Fig.10). Generally in Africa livestock are exposed to Heat Stress which necessitate strenuous complex of physiological activity (Fig.11) to maintain normal *Body Temperature* (Fig.12) and to work towards complementary fulfillment of the *Natural Norms of Viability* (Fig.13). These rigorous activities have to be augmented in case of exposure to *Direct Solar Radiation* and/or Shortage of Water (Tables, 2 & 3) as encountered in *Arid and Sahara* regions and in occasionally outbreaks of Droughts.

Table 2. Percentages of variation (- = decrease, otherwise increase) in blood traits of buffaloes and cattle breeds in response to solar radiation for 2hrs(during summer in Egypt (temp, in shade 35° C) (Shafie and Baderldin, 1962)

Items	Buffaloes	Native cattle	Shorthorn Crosses	Dairy Shorthorn
Physical characteristics:				
Viscosity	- 07.2	- 0.7	- 4.4	- 11.7
PH	- 000.6	000.3	000.0	- 001.1
Chemical constituents: (/100 ml)				
Total protein	- 011.9	004.4	028.6	- 029.4
Albumin	010.8	- 002.5	016.4	013.4
Globulin	- 024.2	007.4	049.3	- 051.7
Fibrinogen	000.0	032.7	- 004.5	015.7
N.P.N	- 011.3	- 001.3	028.7	- 032.3
Creatinine	008.2	- 006.0	010.0	005.6
Haemoglobin	- 002.4	- 002.2	- 003.7	- 008.1
Sugar	- 015.7	003.6	014.5	006.2
Total phosphates	050.3	005.7	009.7	- 003.4
Inorg. Phosphates	085.3	012.4	004.5	001.2
Haemaological picture:				
Haematocrit	- 007.2	- 001.8	000.0	- 012.9
R.B.C. count	- 006.1	000.3	014.9	- 001.2
W.B.C. count	- 003.2	- 001.8	016.6	000.0
Lymphocytes %	- 006.7	008.0	- 012.0	- 004.7
Monocytes %	- 011.5	003.0	044.6	- 022.1
Eosinophils %	- 040.0	000.0	600.0	- 014.1
Basophils %	133.3	100.0	075.0	- 100.0
Neutrophils %	056.6	- 021.9	055.0	090.0

Table 3. **Mean ± S.E. of extra-cellular fluid (ECF); intra-cellular fluid (ISF); plasma volume (PV); Na^+ and K^+ concentrations (mg/100 ml) of buffalo males before (B.) and after (A.) exposure to solar radiation (SR) under hydration and dehydration (D) conditions (Ashour and Shafie, 1993)**

Item		Hydration		Dehydration		Effect of stresses		
		B.SR	A.SR	B.SR	A.SR	D	SR	Combined
		(a)	(b)	(c)	(d)	(c-a)	(b-a)	(d-a)
ECF	L	036.9	041.9	049.1	053.7	012.2	005.0	016.8
		008.2	010.3	008.6	009.1			
	Ml/KgBW	234.6	262.9	318.9	349.7	084.3	028.3	115.1
		021.9	029.6	014.3	016.8			
ISF	L	028.9	033.8	038.8	041.8	009.9	004.9	012.9
		006.7	008.7	007.1	007.9			
	Ml/KgBW	182.3	210.1	251.0	269.7	068.7	027.8	087.4
		017.3	025.9	014.4	016.8			
PV	L	008.0	008.2	010.3	011.9	002.3	000.2	003.9
		000.4	001.6	001.6	001.4			
	Ml/KgBW	052.2	052.9	068.1	093.1	015.9	000.7	040.9
		006.4	005.3	003.1	000.0			
Rumen Fluid	Na^+	357.1	364.1	425.6	351.5	068.5	007.0	-005.6
		005.8	009.6	014.1	005.5			
	K^+	192.6	219.3	240.0	148.6	047.4	026.7	-044.0
		005.6	031.7	012.5	011.0			
Plasma	Na^+	415.8	419.3	406.4	418.3	-09.4	003.5	002.5
		005.5	003.2	005.6	005.8			
	K^+	053.5	058.2	054.2	054.6	000.7	004.7	001.1
		001.2	000.8	002.5	001.0			
Urine	Na^+	122.4	155.1	094.4	181.4	-28.0	032.7	059.0
		027.1	032.0	016.3	011.6			
	K^+	881.4	588.4	769.6	660.9	-111.8	-293.0	-220.5
		162.5	128.6	081.5	070.7			

It has been evident that *Tropical and Subtropical livestock Breeds* have characteristic *Morphological Features, Physiological Capabilities and Behavioral Patterns* to coup with their natural habitats, in contrast with the case of *Temperate Zone issued Breeds* facing these African conditions. Table (4) illustrates, differences, in grazing behavior of sheep breeds, during hot summer in a desert area in Egypt.

Table 4. Difference of subtropical (Egyptian) and temperate sheep breeds in grazing behaviour in cultivated pasture in desert area in Egypt during hot summer (30 ° C at 09.00 h to 35 ° C at 12.00 – 16.30 h) (Sharaf eldin and Shafie, 1965)

Day Hours	Minutes spent on															
	Grazing in sunny area				Grazing under trees shade				Idling in the shade				Lying in the shade			
	Os.	T.	C. M.	Fl. M.	Os.	T.	C. M.	Fl. M.	Os.	T.	C. M.	Fl. M.	Os.	T.	C. M.	Fl. M.
1st	60	47	42	15	-	5	9	16	-	5	9	28	-	3	-	-
2nd	40	25	13	8	1	2	20	2	14	19	27	37	-	14	-	13
3rd	18	7	10	7	-	-	3	1	34	36	31	25	4	17	16	27
4th	7	2	-	1	1	-	-	-	44	38	48	34	4	20	12	25
5th	-	3	1	-	-	-	-	1	32	45	41	20	28	12	18	39
6th	55	15	15	-	-	-	2	-	-	33	31	28	3	12	12	32
7th	60	10	13	1	-	1	8	18	-	42	35	23	-	7	4	18
8th	-	21	12	3	-	-	10	50	60 *	32	34	6	-	7	4	1
Total	240	130	106	36	2	8	52	88	124+60	250	256	201	39	92	66	155

Sheep breeds: OS. Egyptian Ossimi, T. Texel, C.M. caucasian Merine, Fl.M. Fleisch Merino

* The Ossimi breed was idling in sunny area

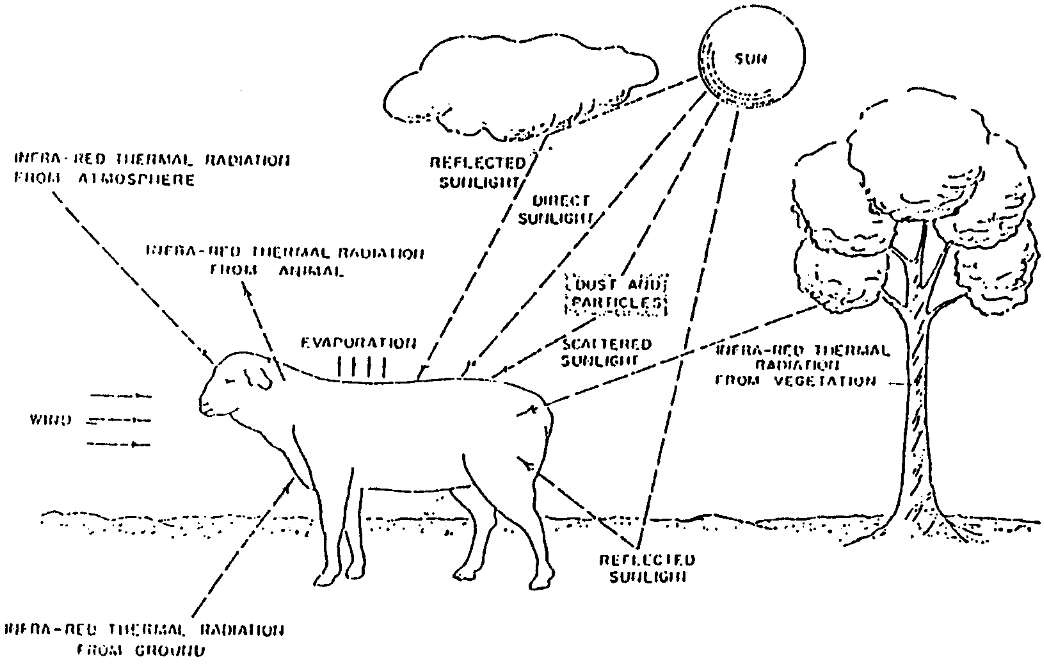
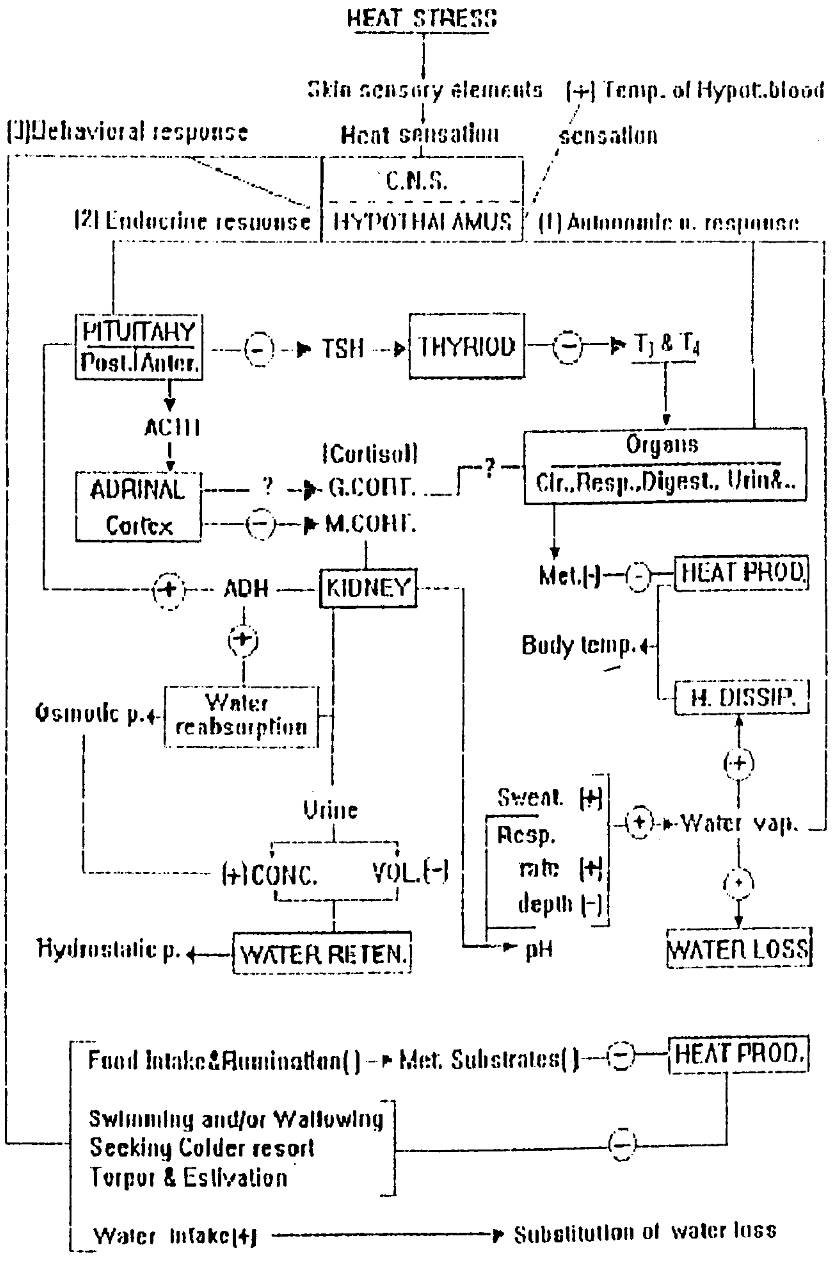


Fig. 10: Streams of radiant energy onto and from the animal in its natural environment



? = changes by increase or decrease in harmony with changes in the body internal conditions.

Fig. 11: Neural and endocrinological reactions in physiological and behavioral responses of livestock animals to environmental heat stress (Shafie, 1994).

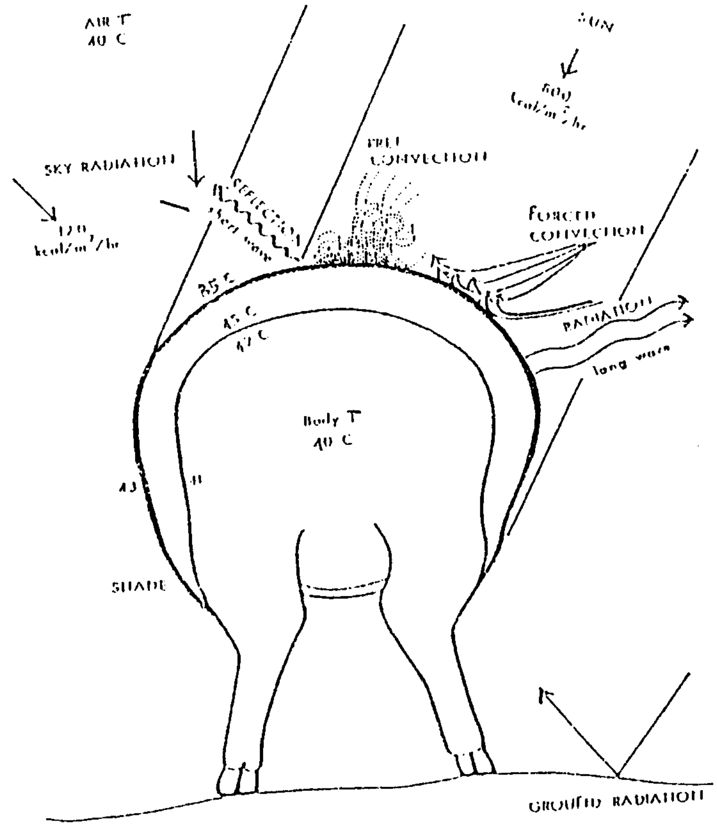
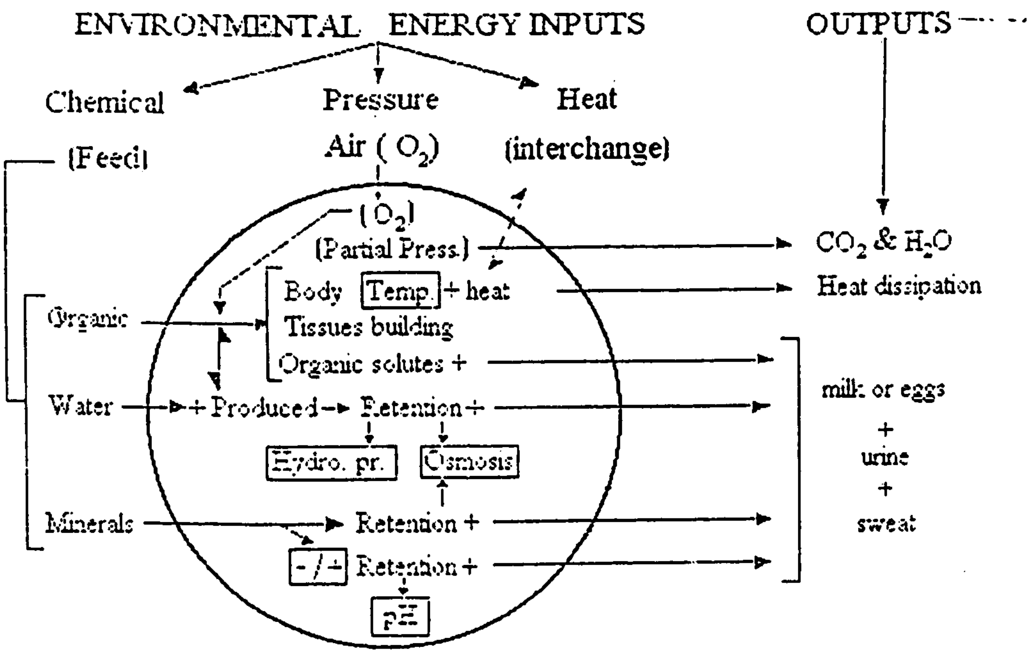


Fig. 12: Heat load imposed on a sheep under direct solar radiation with air temperature 40 ° C and 10 mm vapour pressure, and the balance of heat input by heat output (dissipation), of Merino sheep with m^2 surface, average fleece temperature 60 ° C, and body temp. 40 ° C. (kc/m^2/h) (Macfarlane, 1964).

Input		**Output**	
Solar radiation (direct)	240	Long wave radiation	190
Sky radiation (diffused)	60	Convection in still air	60
Ground radiation	50	*Non evaporative dissipation*	250
Metabolic heat	40	*Evaporative dissipation*	140
Total	390	Total	390



Specific Norms of Biophysical Conditions of Life : Temp., Osmosis, pH. and Hydrostatic pressure.

Fig. 13: Response of vital biophysical norms (Temp., Osmosis, pH and Hydrostatic pressure) within the animal body in counteraction to environmental energy input (Shafie, 1994).

Biological Performance

Hot conditions reduce the efficiency of food utilization (Fig.14), irrespective of the type and quality of feed, consequently drop in growth rate (body weight) particularly in temperate breeds (Fig.15). Severe heat stress causes profound decrease in milk yield, such effect exaggerated by dense humidity and direct solar radiation (Fig.16).

Reproductive Performance

Climatic stress affect male and female reproductive traits (Figs.17&18 and Tables 5 & 6). The ovarian hormones and (LH) hormone fluctuate in patterns related to seasonal climatic conditions, particularly temperature and light (Figs.19&20). In general, the hormonal profile and both reproductive behavior and performance are affected by inevitable changes due to hot conditions.

Indirect Effect of Climate on Livestock:

Climatic elements have indirect effect, on *vitality, viability, fecundity and productivity* of livestock, in some cases more significantly than the direct effects, particularly in humid and semi-humid regions. The effects can be discussed in two major effective categories:

1) *Natural Feed Resources*, in the regional plant associations (Fig.9), *with value in livestock feeding.*
2) *Parasites and Epidemic Diseases.*

Natural Feed Resources

Type of natural vegetation (also cultivated crops) are restricted by climatic element (temperature, humidity, precipitation alongside light duration and intensity). Of course the type of soil (physical and chemical characteristics), generally determined by climate, has a role in the plants associations. These plant associations (Fig.9) differ in their value for livestock grazing in accordance with abundance and nutritive quality of pasture plants.

The high temperature in the tropics and subtropics, generally all Africa, has effect on the growth of vegetation types (Fig.21). Moreover it affects the foliage of the plants (Table 7), thus affecting the development of the nutritive value.

The latitude location and altitude levels determine the general features of climatic temperature and precipitation, thus controlling the vegetation density and characteristics. Table (8) shows the difference between tropical pasture plants in palatability, thus voluntary intake, and digestibility. Figure (22) depicts the superiority of temperate grasses over tropical grasses in digestibility. Figure (23) illustrates the higher content of crude protein in legume than in grass pasture plants of the tropics, thus setting the quality of pasture in a given range. The pasture quality in any region is reflected on livestock grazing behavior and the most suitable type of ruminants, ultimately, the biological and economical feasibility of the system of pasture utilization.

The quality and seasonality of the pasture is reflected directly on the growth of grazing livestock as evidenced in figures (24 & 25). It is clear in these figures that growth of steers was hampered throughout the dry season. There are no growth increment in the young animals (Fig.24). The older animals suffer a drop in body weight with the start of the dry season, this effect extends for a period in the beginning of the wet season, a phenomenon known as *Green Grass Loss* (Fig.25). The animals show a compensatory growth in the rest of the wet season. Williamson and Payne (1988) postulated that the slower maturing indigenous breeds show better response in that compensatory growth than the rapidly maturing exotic temperate breeds, as generally considered after a period of under-nutrition.

The above mentioned authors stated " The effects of seasonality in forage production on the growth of beef cattle are fundamentally the same in all those areas of the tropics where there is a definite dry season. The practical results vary in accordance with the length and severity of the dry season. However, even in the humid tropics where planted pastures are grazed, seasonality can still create managerial problems".

The condition of the pasture is an inevitable constraint on the *Stocking Rate* by livestock. The rate is the number of animal units which could be supported by a precise area of a pasture, the standard area is one hectare, usually for one year. By a reciprocal rate the term *Carrying Capacity* denotes the pasture area sufficient to sustain the feed for one animal unit. This is more practical for determining the available feed resources, particularly in the deficit cases. The *Animal Unit* is the standard value in a comprehensive system of determination incorporating the different ruminant species and ages (Table 9).

Stocking a pasture has to be adjusted to the optimum density to have the maximum economic gain as expressed in figure (26). This optimum stocking could be determine by the following ratio denoted as *Grazing Pressure.* (GP) (Mott, 1960).

Table 5. Effect of heat stress and feeding system, during the last third of pregnancy period, on body temperature and lambing traits (Brown et al., 1997)

Item	*Ewe treatment*		
	Range grazing	Restricted feed	Hot room
No. ewes preg.	15	15	14
Body temperature ° C	¦	038.80 ± 00.10	040.20 ± 00.20
Lambing % - live	167.00 ± 19.00	173.00 ± 15.00	100.00 ± 26.00
Lambing % - total	173.00 ± 18.00	173.00 ± 15.00	150.00 ± 26.00
Avg. birth wt. live, Kg	004.69 ± 00.26	004.16 ± 00.16	003.26 ± 00.30
Lamb condition *	001.90 ± 00.20	002.00 ± 00.10	001.50 ± 00.30

* condition: 1 = Weak, 2 = Avg. and 3 = Strong.

Table 6. Monthly differences in rams semen quality and effect of heat stress (from Curtis, 1983 after Cupps et al., 1960)

Month	Mean maximum daily environmental temperature (° C)	Ejaculate volume (ml)	Sperm concentration (10^9 ml^{-1})	Percent motile	Percent live	Percent abnormal
Oct.	22	1.3	3.4	81	79	6
Nov.	18	1.5	3.3	79	77	7
Dec.	11	1.4	3.6	82	77	9
Jan.	11	1.1	3.1	68	39	14
Feb.	16	1.0	3.4	72	62	15
Mar.	16	1.2	3.4	73	61	15
Apr.	22	1.1	3.1	71	60	18
May	28	0.9	2.5	79	61	20
Jun	30	1.0	2.4	75	63	10
Jul.	34	1.1	2.4	59	49	13
Aug.	37	1.0	1.9	35	25	32
Sept.	33	0.9	1.8	58	23	15

Table 7. Effect of constant 20 or 30 ° C temperature on growth, leaf area, and mean rate of leaf area development in ten grasses and ten legumes (from Whiteman, 1980 after Ludlow and Wilson, 1970)

Species	Plant dry wt. (g)		***Leaf area* (cm^2)**		Rate of leaf area development (cm^2 day^{-1})	
	20 ° C	30 ° C	20 ° C	30 ° C	20 ° C	30 ° C
Grasses						
Brachiaria ruziziensis	0.16	3.06	25	445	0.7	21.2
Panicum maximum (creeping Guinea)	0.83	1.32	50	102	1.4	04.8
P. maximum cv. Hamil	0.12	2.57	16	341	0.4	16.2
P. maximum cv. Petrie	0.21	2.05	31	280	0.9	13.3
P. maximum cv. Common	0.16	2.40	22	356	0.6	16.9
P. coloratum	0.22	1.55	30	174	0.8	08.3
Setaria sphacelata cv. Nandi	0.18	0.56	25	068	0.7	03.2
Cenchrus ciliaris cv. Biloela	0.22	2.75	24	334	0.7	15.9
Chloris gayana cv. Samford	0.20	1.17	26	188	0.7	08.9
Melinis minutiflora	0.11	0.15	11	023	0.3	01.1
Mean	0.20	1.76	26	231	0.7	11.0
Legumes						
Macrotyloma uniflorum *cv. Leichardt*	0.16	1.97	20	443	0.60	21.1
Vigna luteola cv. Dalrymple	0.27	2.16	31	272	0.90	12.9
Centrosema pubeacens	0.05	0.95	07	131	0.20	06.2
Macroptilium atropurpureus cv. Siratro	0.27	1.10	28	196	0.80	09.3
Calopogonium mucunoides	0.02	0.98	04	162	0.10	07.7
Pueravia phaseoloides	0.07	0.84	07	177	0.20	08.4
Glycine wigh tii cv. Tinaroo	0.28	0.72	27	121	0.80	05.8
Desmodium uncinatum cv. Silverleaf	0.15	0.66	18	083	0.50	03.9
D. intortum cv. Greenleaf	0.06	0.34	07	057	0.20	02.7
Lotononis bainesii cv. Miles	0.02	0.02	02	004	0.06	00.2
Mean	0.15	0.97	15	165	0.40	07.8

Table 8. Comparison of dry matter digestibility (DMD) and voluntary intake (VI) values for tropical grasses and legumes from indoor feeding trials with sheep. (from Whiteman, 1980)

Species	Age of regrowth (days)	DMD %	VI g kg^{-1} body $weight^{0.75}$	Reference
Grasses				
Chloris gayana	028	61-4	50-2	[b]
C. gayana	112	49-51	39-45	[b]
Digitaria decumbens	007	64	48	[c]
D. decumbens	084	48-54	-	[c]
Pennisetum clandestinum	052	62	46-50	[c]
Setaria anceps	052	56	48	[c]
S. anceps	102	48	28	[c]
Cenchrus ciliaris	056	56	45	[c]
C. ciliaris	112	46	34	[c]
C. ciliaris	140	41	29	[c]
Legumes				
Lablab purpureus	070	59	64-6	[b]
L. purpureus	130	51	64-6	[b]
Vigna sinensis	070	64	76	[a]
Macroptilium atropurp.	112	50	38	[a]
Desmodium uncinatum	112	54	56	[a]
Lotononis bainesii	182	60	59	[a]
Medicago sativa	060	70	97	[a]

Compiled from; Milford (1967) [a], Milford and Minson (1968) [b], Minson and Milford (1968) [c].

Table 9. Standard animal unit for cattle and sheep classes (from Whiteman, 1980).

Cattle		Sheep	
1 animal unit (a.u.)	= 400 kg steer	1 dry sheep equiv. (d.s.e.)	= 40 kg wether
400 kg steer	= 1 a.u.	wether	= 1 d.s.e.
Calf (1-8 months)	= 0.35 a.u.	Maiden ewe	= 1 d.s.e.
Weaner (8-12 months)	= 0.40 a.u.	Lamb (up to 2 tooth)	= 0.5 d.s.e.
Steer (1-2 years)	= 0.87 a.u.	Breeding ewe	= 1.7 d.s.e.
Breeding cow	= 2.0 a.u.	ram	= 1.7 d.s.e.
Bull	= 2.0 a.u.		

1.0 a.u. (steer) = 8 d.s.e. (wethers)

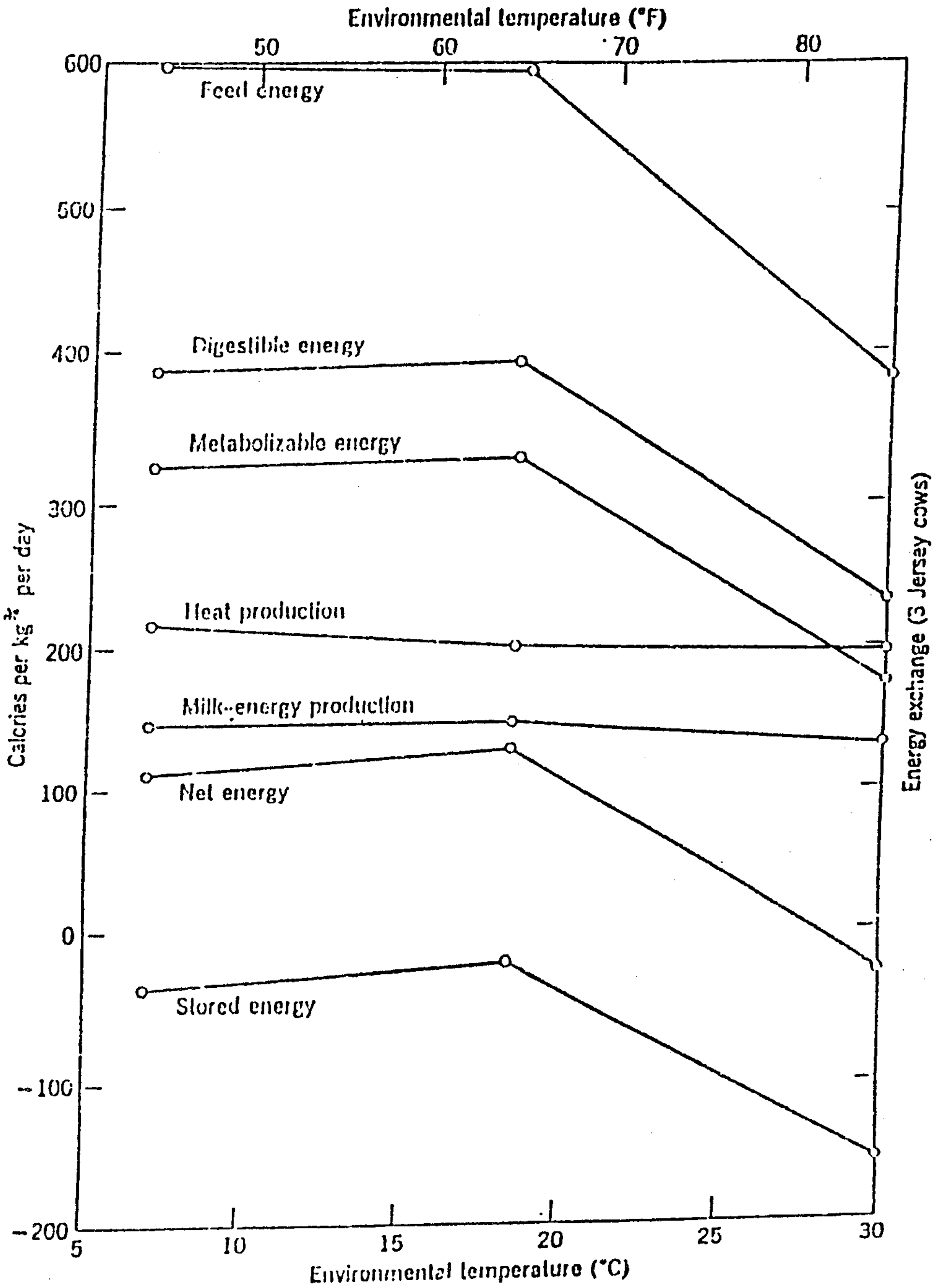


Fig. 14: Effect of environmental temperature on utilization of feed energy by ruminants (Kleiber, 1961).

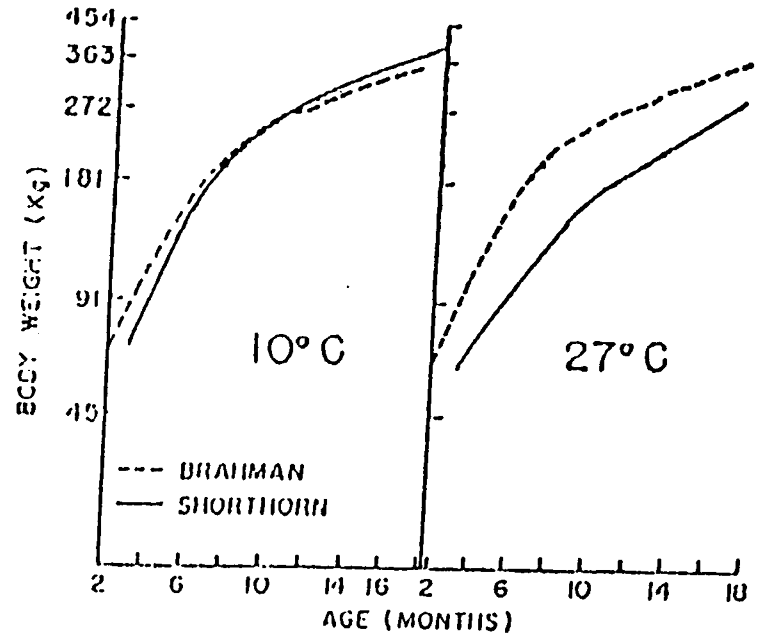


Fig. 15: Influence of environmental temperature on growth rate of cattle (after Johnson, 1957 from Hafez, 1968).

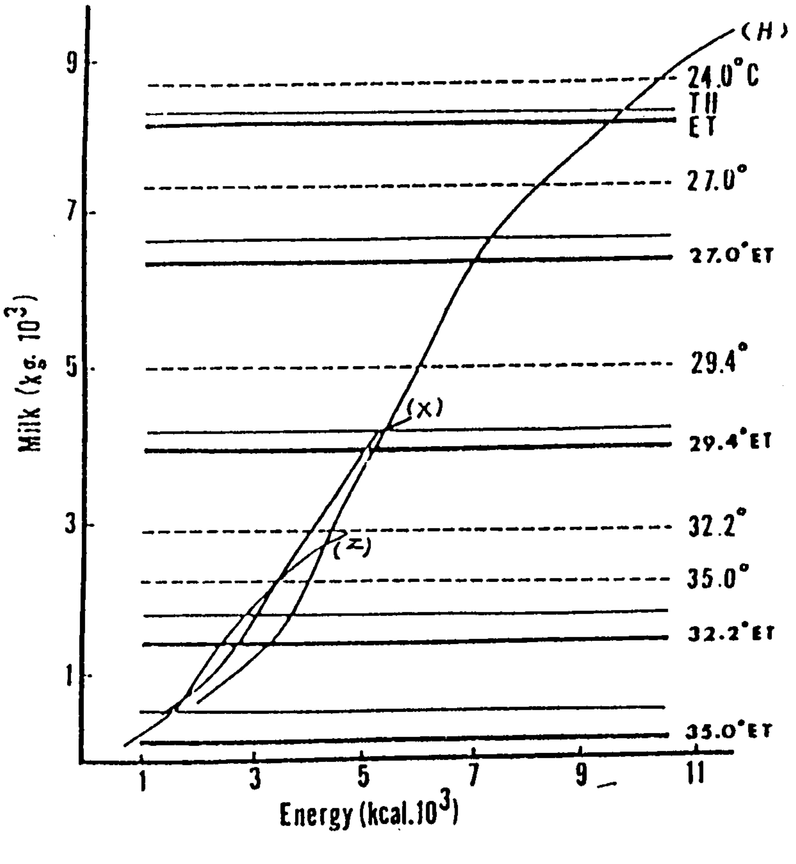


Fig. 16: Influence of air temperature and humidity and solar radiation on intake of feed energy and milk yield of cattle (after Mc Dowell from Kleiber, 1961). (Z) Zedu cows, (H) Holestein and (X) cross breed zebux European. Temp. = ° C at Humidity < 50%. TH = humidity > 60% and ET = additional effect of solar radiation.

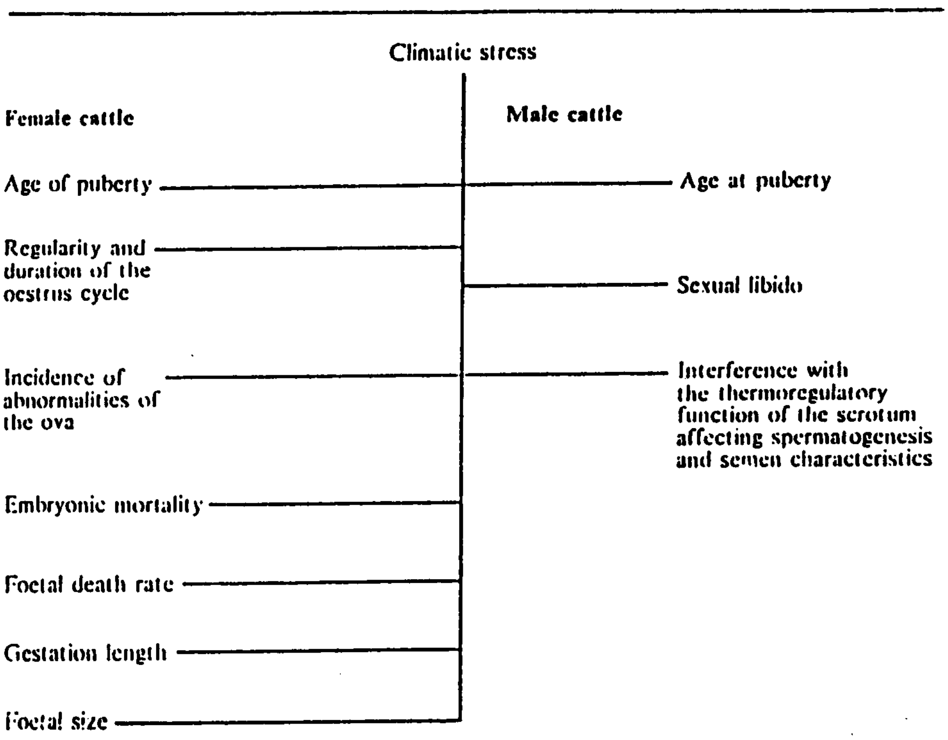


Fig. 17: Reproductive traits of cattle exposed to climatic stress (mainly heat) (Williamson and Payne, 1988).

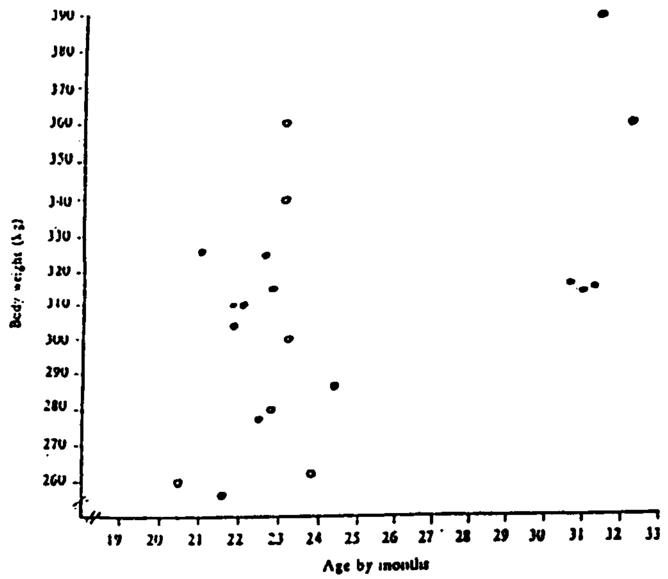


Fig. 18: Effect of seasonal coditions (0 = hot, ? = cold) on age and body weigh at puberty of buffalo heifers (Barkawi et al., 1989).

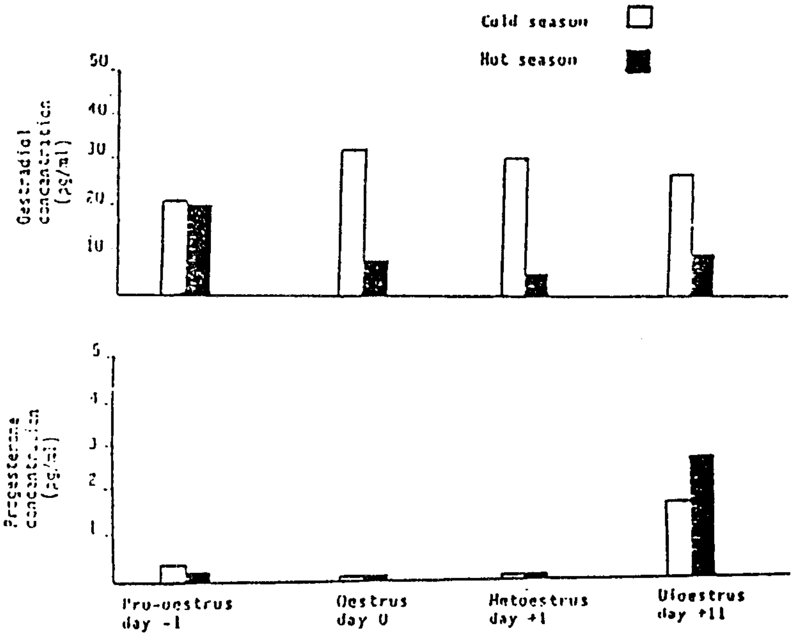


Fig. 19: Seasonal pattern of sex hormones in Egyptian buffalo cows (Shafie et al., 1982).

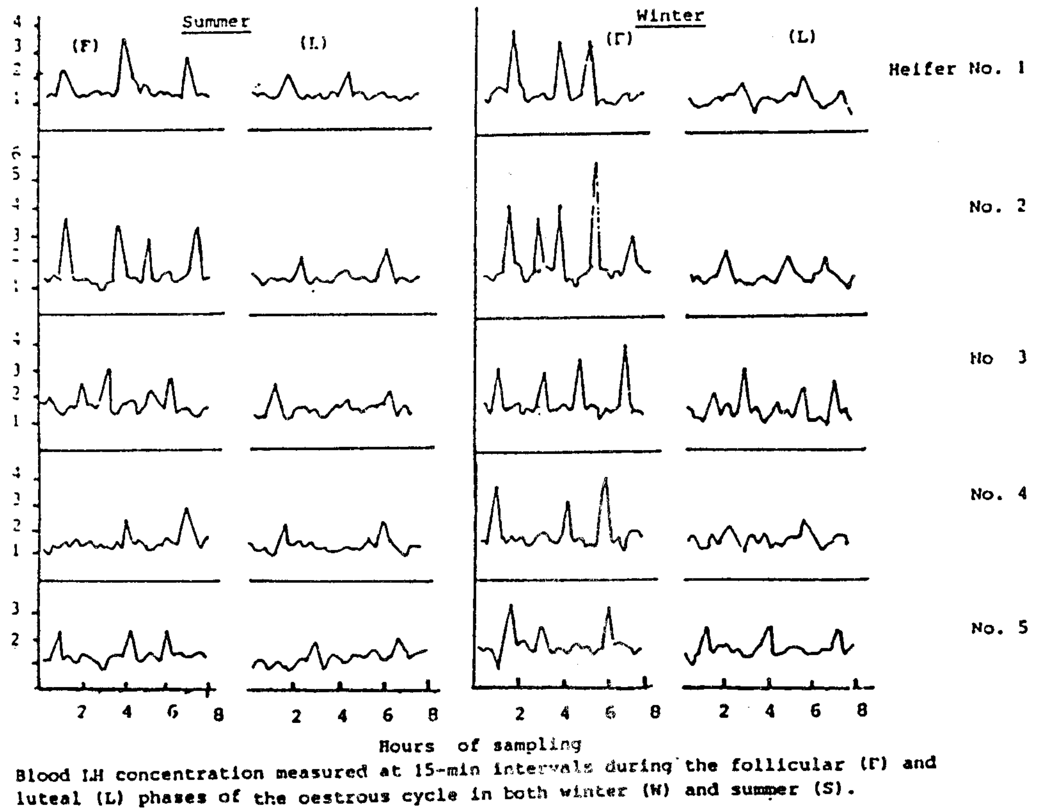


Fig. 20: Pulsatile secretion of LH hormone in cycling buffalo heifers as affected by season and phases of ovarian cycle (Aboul -Ela and Barkawi, 1988).

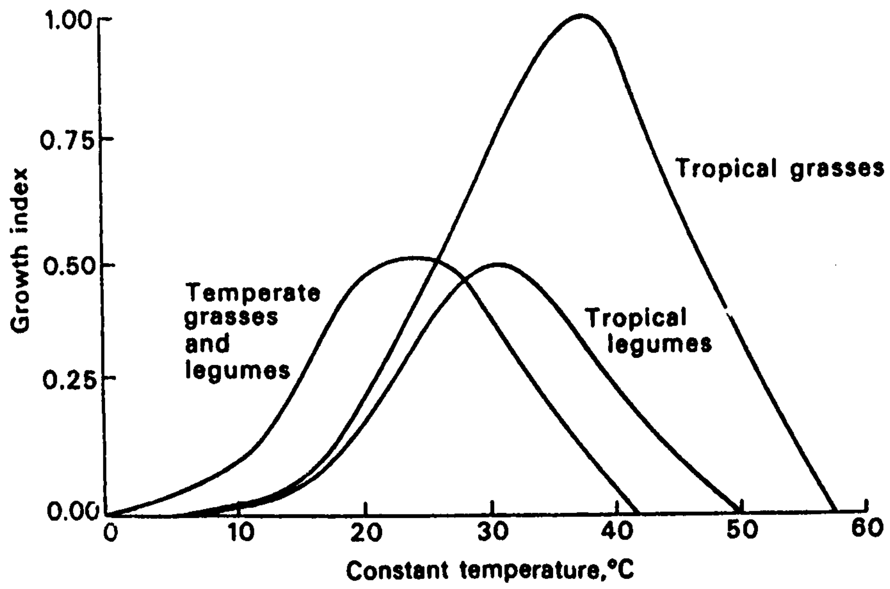


Fig. 21: Dry matter production of Temperate and Tropical pasture species in respons to temperature. Growth index represents production relative to maximum production of tropical grasses under their optimum temperature (Whiteman, 1980).

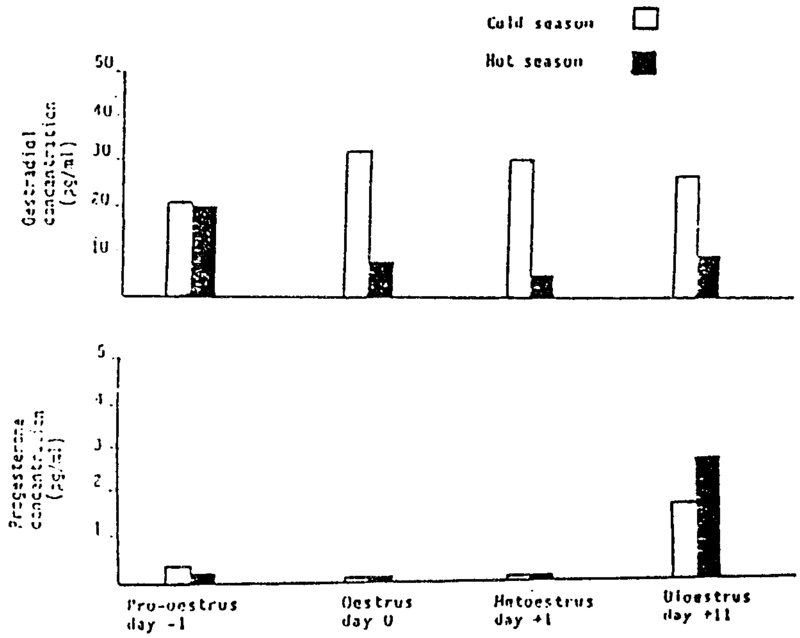


Fig. 19: Seasonal pattern of sex hormones in Egyptian buffalo cows (Shafie et al., 1982).

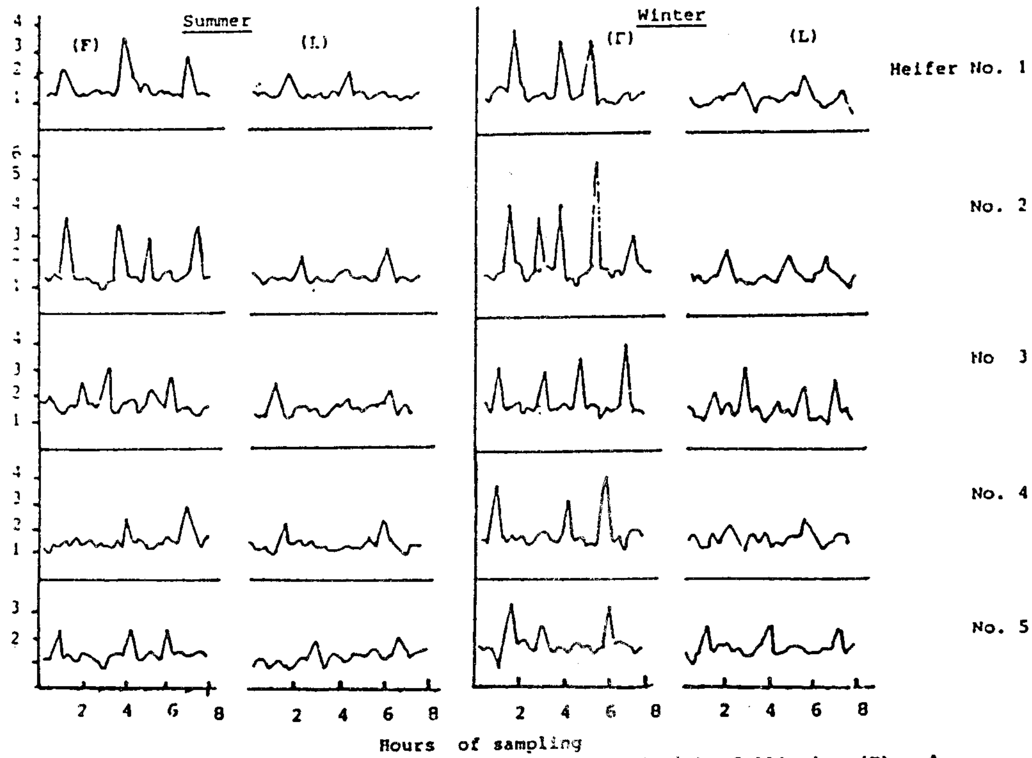
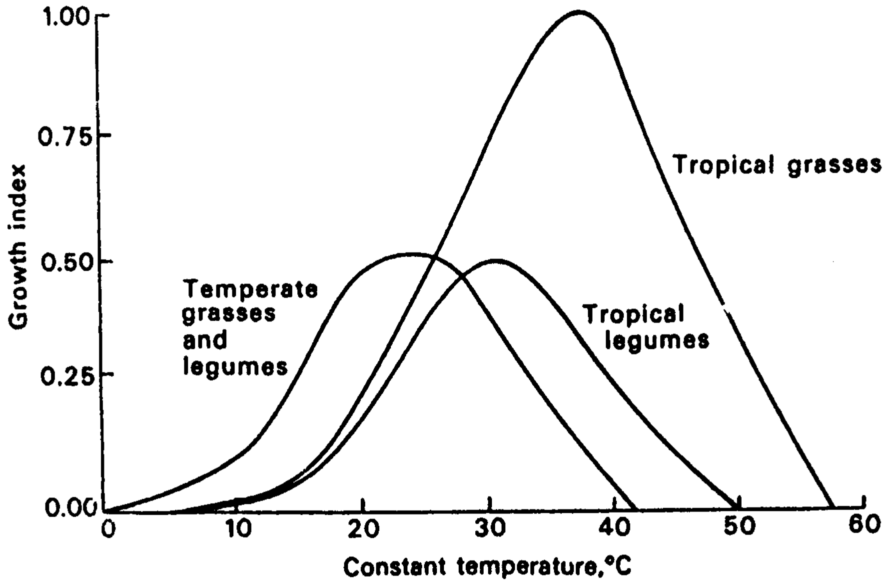


Fig. 20: Pulsatile secretion of LH hormone in cycling buffalo heifers as affected by season and phases of ovarian cycle (Aboul -Ela and Barkawi, 1988).



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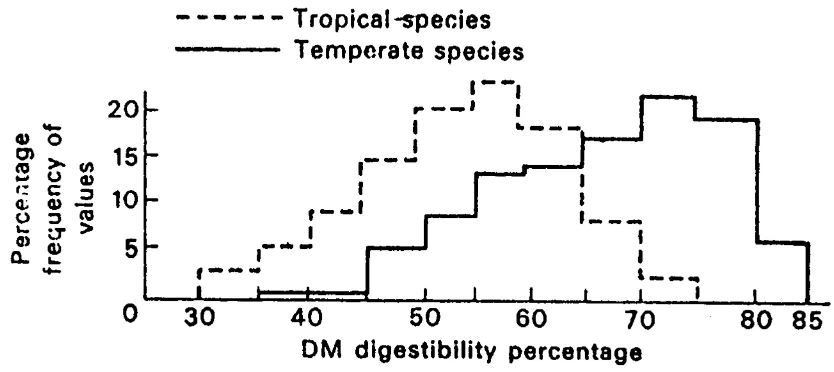


Fig. 22: Frequency distribution of values for digestibility of tropical and temperate grasses (from Whiteman, 1980 after Minson and McCleod 1970).

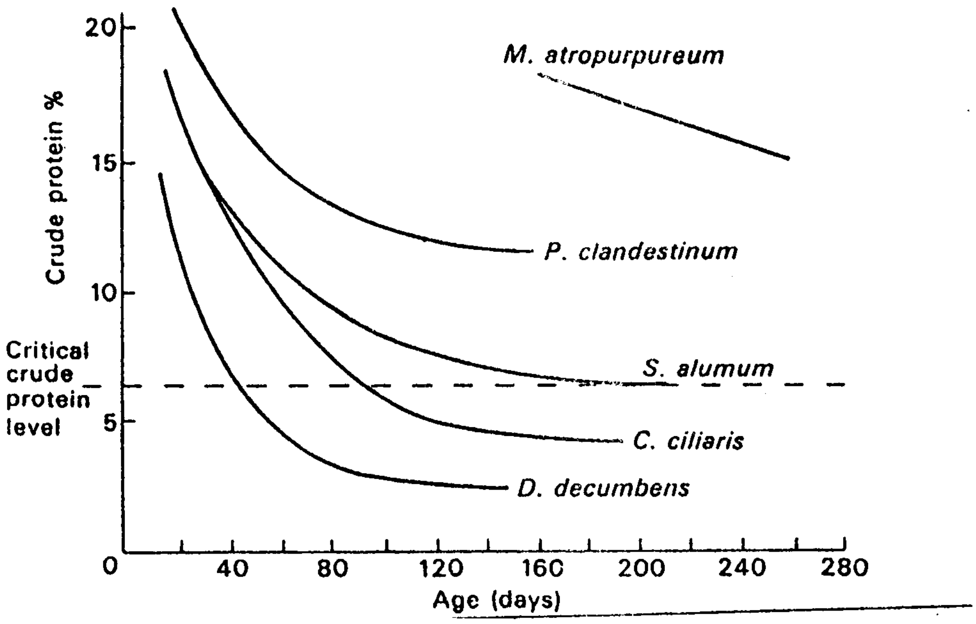


Fig. 23: Relationship between crude protein content and plant age in four grasses and the legume M. atropurpureum (Milford and Haydock 1965).

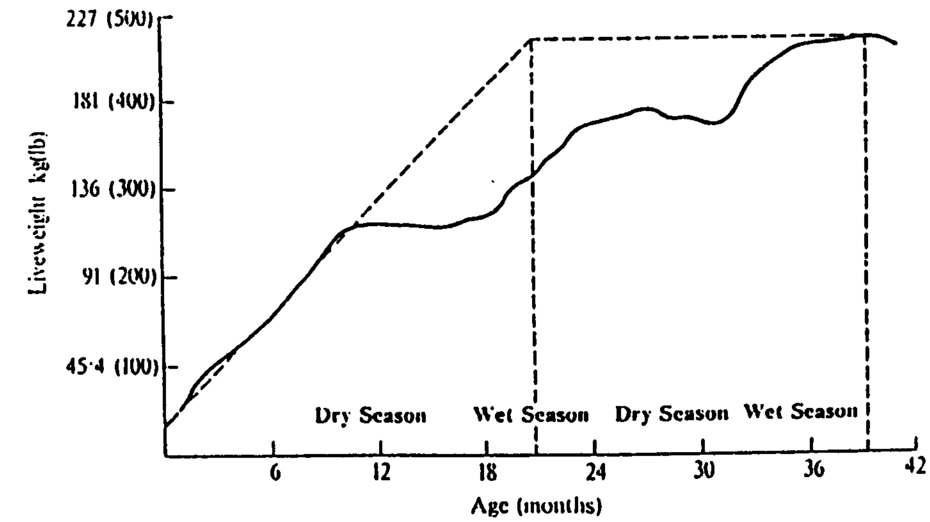


Fig. 24: Seasonal cyclic growth pattern of extensively managed cattle (after Touchberry, 1967 from Williamson and Payne, 1988).

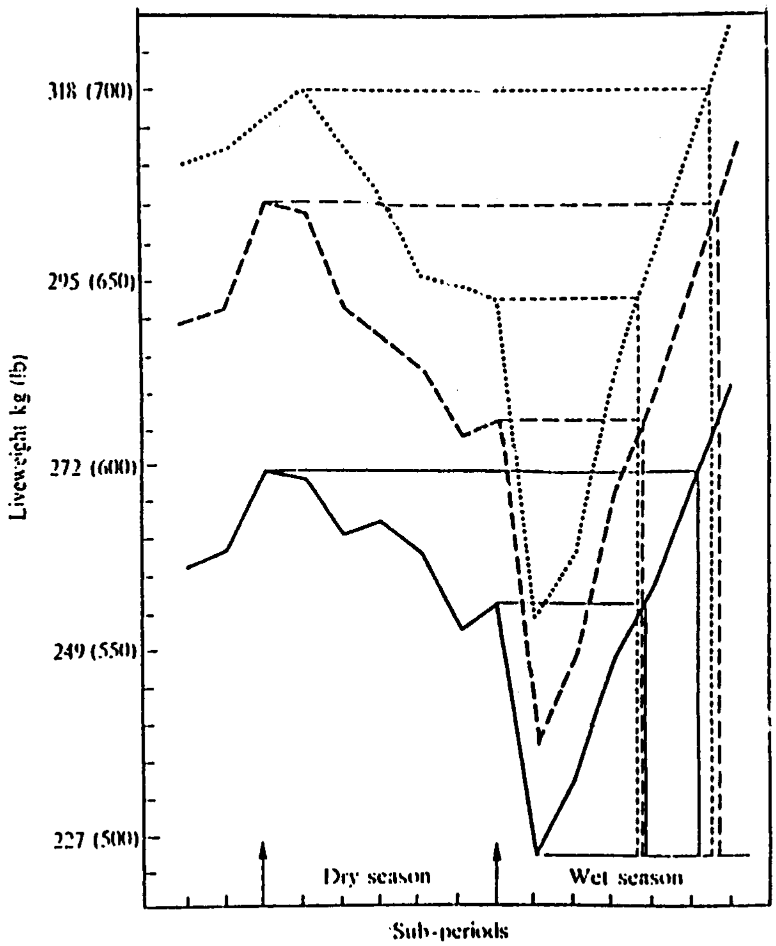


Fig. 25: "Green grass" loss in live weight of cattle at the end of the dry season (... control twins, --- experimental twins, __ Masai steers)(after Payne, 1965 from Williamson and Payne, 1988).

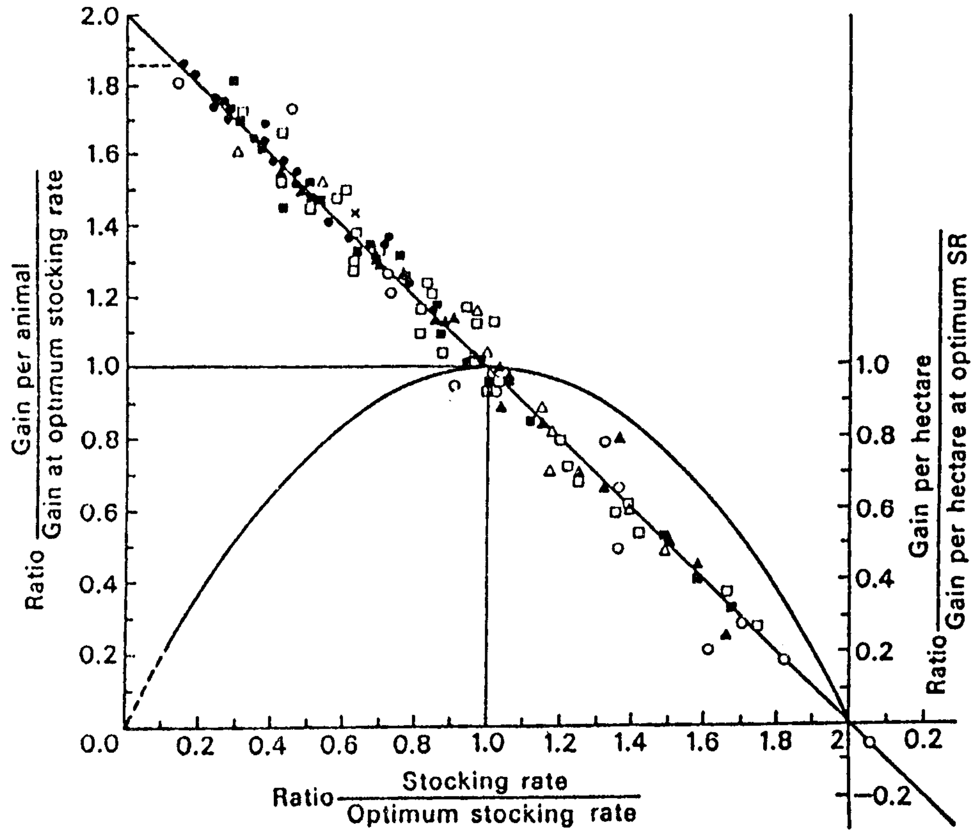


Fig. 26: Relation between Stocking Rate (SR) and live body Weight Gain, per Animal (G/A) and per Hectar (G/H); from grazing experiments with varios pasture species under wide environmental conditions (after Jones and Sandland, 1974 from Whiteman, 1980).

$$GP = \frac{Dry\ matter\ demand\ animal^{-1}\ day^{-1}.no.\ animal\ ha^{-1}}{Dry\ matter\ available\ .\ day^{-1}.\ ha^{-1}}$$

Proper stocking rate is decided in accordance with the natural level of rain fall, native. Pasture plants, range management and grazing system. The experience in the applicable combinations of these items is reflected on the livestock production up to the best economic return, with good regard of the sustainability of the rangeland. The following tables (10, 11, 12) present data on, beef, lamb and milk production in some conditions of pasture and grazing systems.

Table 10. Comparison of beef cattle liveweight gains per hectare from native pastures, native pastures oversown with a legume, or oversown and fertilizer applied (from Whiteman, 1976)

Location	Natural pasture	Legume oversown	Liveweight gain (kg ha^{-1})			
			Unimproved	Oversown	Oversown and fertilizer	Time (days)
Central Queensland	Heteropogon	S. humilis	11	85	-	365
Central Queensland	Heteropogon	S. humilis	32	103	163	365
Katherine NT	Themeda, Sorghum	S. humilis	-5.5	-	+150	112
Uganda	Chloris Panicum, Hyparrhenia	S. guianensis	269	362	366	343
		C. pubescens	245	339	373	343
Papua-New Geinea	Imperata	S. guianensis	78	101	-	300
			78	112	-	420
Centeral Queensland	Heteropogon	Siratro	43	-	115	365
Southern Queensland	Bothriochloa-Eragrostis	Siratro	75	-	91	199
			92	-	177	264
			72	-	143	213

Table 11. Effect of stocking rate and grazing method on lamb production from hill pastures in New Zealand (Kissock, 1966)

Stocking rate (ewes ha^{-1})	Lamb meat production (kg ha^{-1})	
	Rotational	Set-stocked
12.4	287	314
14.8	393	400
16.1	444	364
17.3	430	333
18.5	442	341

Table 12. Effect of stocking rate on milk yield of kikuyu pastures fertilized at 336 kg N ha^{-1} (Colman and Kaiser, 1974)

	Stocking rate (cows ha^{-1})	Milk yield (FCM kg cow^{-1})	Milk yield (kg ha^{-1})	lactation period (days)	Milk yield (kg cow^{-1} day^{-1})
1967-8	2.47	2467	6093	284	8.68
(rainfall	3.29	2312	7606	281	8.23
1050 mm)	4.94	2068	10216	278	7.44
1968-9	2.47	1964	4851	274	7.17
(rainfall	3.29	1750	5757	253	6.92
747 mm)	4.94	1733	8561	253	6.85

Systems of Livestock Rearing:

Livestock rearing is, imperatively, an integral sector in land-use for agricultural activities. The rearing systems very in accordance with the vegetative potentialities of the utilized area (zone) and level of engagement in plant cultivation. Table (13) shows the occupation of bovines (buffaloes and cattle) in the world tropical agriculture system in the year (1976). The last three systems in the table are that utilised primarily for livestock natural grazing.

Table 13. Estimates of the number and percentage, from the total, of bovines in the major tropical agricultural systems (Willamson and Payne, 1988 after Payne, 1976)

Tropical agricultural systems	No. bovines (million)	No. bovines as percentage of total	Type of bovine reared
Migratory shifting cultivation	6	1	Cattle
Sedentary shifting cultivation	30	5	Cattle and buffaloes
Sedentary subsistence cultivation	290	46	Cattle and buffaloes
Regulated ley farming	15	2	Cattle
Perennial crop cultivation	15	2	Cattle and buffaloes
Nomadic herding	32	5	Cattle
Transhumance	63	10	Cattle
Ranching	180	29	Cattle

Note: Bovines include cattle and buffaloes and are expressed as cattle units, with 1.00 buffalo being considered equivalent to 1.25 cattle.

Natural Grazing Systems:

The three natural grazing systems are that sustained on natural vegetation, whatever the level of range management. Each of these systems is the proper utilization of the grazed zone with its particular ecosystem. Proper grazing management, in any system, is a must for sustainability of the rangeland to avoid its degradation. The following review, on this respect, is cited after Williamson and Payne (1988).

Nomadic Herding

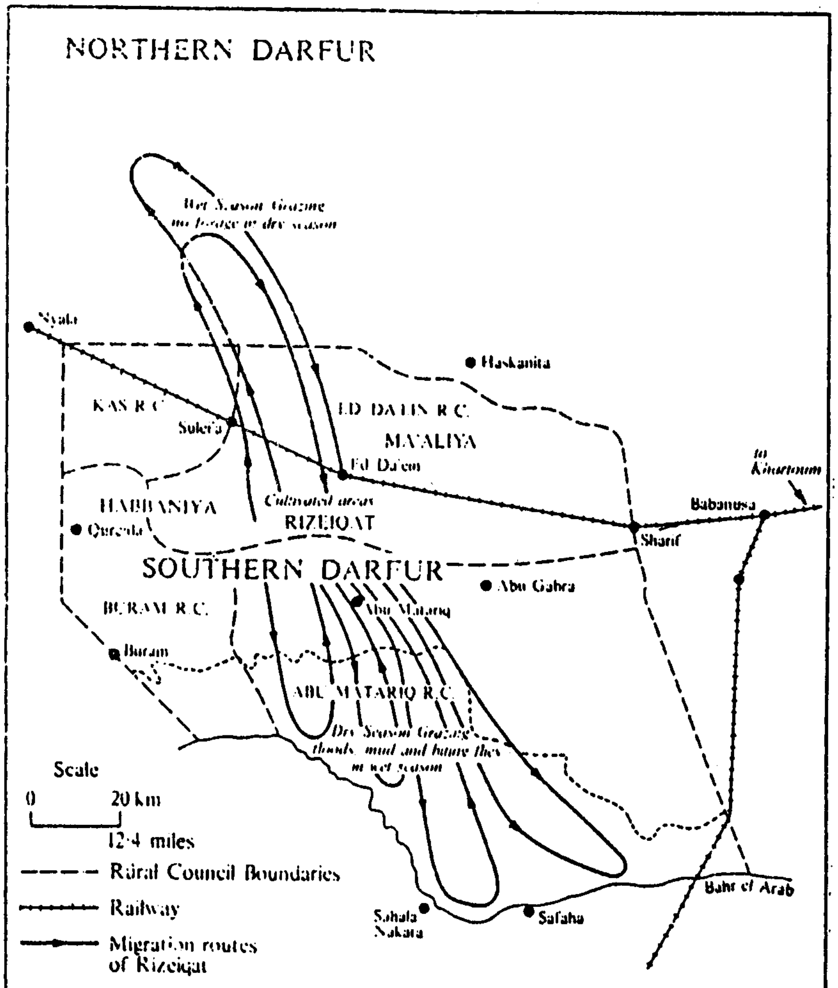
This practice is now limited to minor areas; Indian Sub-continent, some areas of Western Asia and larger areas in West, Northeast and East Africa. In general, tropical areas where nomadism is still practiced are characterized by a dry climate and a sparse human population of 0.8 to 10 people per km^2. Nomads utilize other livestock besides cattle, Particularly camels, sheep and goats. They also usually own donkeys, and in some areas horses . The total amount and the seasonal distribution of rainfall, the availability of free water and the prevalence of disease and parasites determine to some extent what type of livestock is utilized. In Africa cattle are the most important type of livestock raised by nomads, whereas in western Asia sheep are more important. Some nomads, such as the Baggara Arabs of the *Western Sudan*, may move 'horizontally' "North - South" (Fig.27). In the dry season they migrate southwards to the higher rainfall region around Bahr El Arab river, while during the wet season they retreat northwards to escape the biting flys and the mud and to graze the ephemeral forage in the semi-arid lands. Others, such as some tribes in *Ethiopia and East Africa*, move vertically "East - West" into the more humid higher-altitude country during the dry season, returning to the semi-arid lowlands during the wet season.

Nomadism is normally practiced under marginal conditions, carries high production risks and requires large areas of range grazing. In many instances it is a form of large-scale rotational grazing that could be ecologically efficient.

Transhumance (Semi-nomadic herding)

Semi- and partial-nomadic herding system are of very considerable importance throughout *West, Northeast and East Africa and in Malagasy Republic*. They also exist in Western Asia and in the Indian Sub-continent. Transhumants have a village base where they cultivate crops during the wet season, but during the dry season some or all of them move with their herds to areas where they believe that the grazing is superior, returning to their village for the next cropping season.

As an agricultural system, transhumance is not normally superior to nomadism. Indeed as the herds of transhumants often have less room to maneuver, the cattle are usually inferior in quality to those of the true nomads. Nevertheless, transhumance has social advantages as the participants can be relatively easily provided with desirable social services such as education and health.



The homeland or *dar* of the Rizeiqat is adjacent to the railway. This is where the main areas of cultivation are located. The herdsmen with their livestock move southwards towards the seasonally flooded areas adjacent to the Bahr el Arab during the dry season. When the rains come they move northwards through the *dar* lands into the semi-arid areas, returning southwards as the wet season ends. The annual migratory cycle may exceed 360 km (224 miles)

Fig. 27: Nomadic tracking annual cycle; of the Rezeiqat tribe, in the Western Sudan (after Hunting Technical Service, 1976 from Williamson and Payne, Williamson and Payne, 1988).

Ranching

Ranching is the commercial alternative to the various types of nomadism. In the tropics large-scale ranches are found in both the semi-arid and humid regions of Mexico, Central America, the Caribbean and South America; *in the tsetse-fly-free areas of East and South Central Africa*, in Australia an the Pacific islands and in small numbers in specific locations in Southeast Asia, particularly in the Philippines. It is the preferred use of land that is inherently infertile, semi-arid or inaccessible. In Central and South America it is the prime reason for which large areas of primeval rain-forest are being felled. The form of management adopted depends in the first place on the intensity of stocking; this in turn depends primarily on the climate environment and above all on the total annual rainfall, the seasonal distribution of that rainfall and the repeatability of these factors. In the humid tropics and particularly in the humid equatorial zone, stocking rates could be as high as one or more cattle units per hectare (2.5 acres). In the arid tropics stocking rates may be very low. For example in Northern Australia stocking rates may be as low as one cattle unit per 259 ha (1 mile^2), so that the ranches have to be very large to remain viable economic units.

The major technical objectives of ranch management are to decrease annul fluctuation in cattle numbers and seasonal fluctuations in live-weight, maximize reproductive performance, minimize mortality, and maintain and if possible improve the grazing. All these practices tend to intensify production on the ranch. In ranching systems outputs generally depend upon inputs, but economic viability may not depend upon maximizing outputs.

Degradation of Rangeland

The continuos increase in human population raised the need for more food supply, by any means, particularly staple grains and animal protein commodities. Most of the national required supply was atchieved by turning the natural pasture areas into cultivated land, (alongside the means of improving plant and livestock productivity). This turn in land use was overdone in the rangeland by unorganized expansion of migratory shifting cultivation and/or ley farming. This turn in land use led to a severe degradation in the land most drastic in the arid and semi-arid regions. Figure (28) shows the sequences of land degradation in the *African Savanna* due to expanded cultivation.

Another adverse use of the range is the overstocking of the rangeland, thus overgrazing leads to the destruction of the regional balance of the natural plant complex. Figure (29) expresses the change in pasture quality through years of overgrazing. In that pasture the best palatable, high nutritive, plants decrease successively, correspondingly the less palatable plants increase. The most degrading feature is the encroachment by invader plants which are not palatable. Moreover these invaders do not protect the soil and moisture with subsequent erosion of the land, may reach desertification. In the year 1994 Brown and Kane published the following comments. "Although the data for grassland degradation are sparse, the trends are no less real. This problem is highly visible throughout *Africa*, where livestock numbers have expanded nearly as fast as the human population. In 1950, 238 million Africans relied on 273 million livestock. By 1993, the human population had increased to 665 million while that of livestock reached 564 million. In this continent where grain is scarce, 190 million cattle, 206 million sheep, and 168 million goats are supported almost entirely by grazing and browsing. Everywhere outside the tsetse-fly belt, livestock are vital to the economy. But in many countries their numbers exceed grassland carrying by half or more. A study charting the mounting pressures on grasslands in nine southern African countries found that the capacity to sustain livestock is diminishing. As grasslands deteriorate, soil erosion accelerates, further reducing the carrying capacity and setting in motion a self-reinforcing cycle of ecological degradation and deepening human poverty".

Further warning on degradation of rangeland was published in 1998 by the United Nations Environment Program (UNEP) in collaboration with the World Meteorological Organization (WMO). The assessment of the existing circumstances of the rangeland and the expected deterioration by changes in global atmosphere is exposed in the Intergovernmental Panel On Climate Change "The Regional Impacts Of Climate Change" (Watson et al., 1994). "In Africa today, tropical forest; and rangelands are under threat from population pressures and systems of land use. Generally apparent effects of these threats include loss of biodiversity, rapid deterioration in land cover, and depletion of water availability through destruction of catchments and aquifers. Changes in climate will interact with these underlying changes in the environment, adding further stresses to a deteriorating situation. A sustained increase in mean ambient temperatures beyond 1 °C would cause significant changes in forest and rangeland cover; species distribution, composition, and migration patterns; and biome distribution. Many organism; in the deserts already are near their tolerance limits, and some may not be able to adapt further under hotter conditions. Arid to semi-arid subregions and the grassland areas of *eastern and southern Africa*, as well as areas currently under threat from land degradation and desertification, are particularly vulnerable. These effects are likely to be negated, however, by population pressure on marginal forests and rangelands. Adaptive options include control of deforestation, improved rangeland

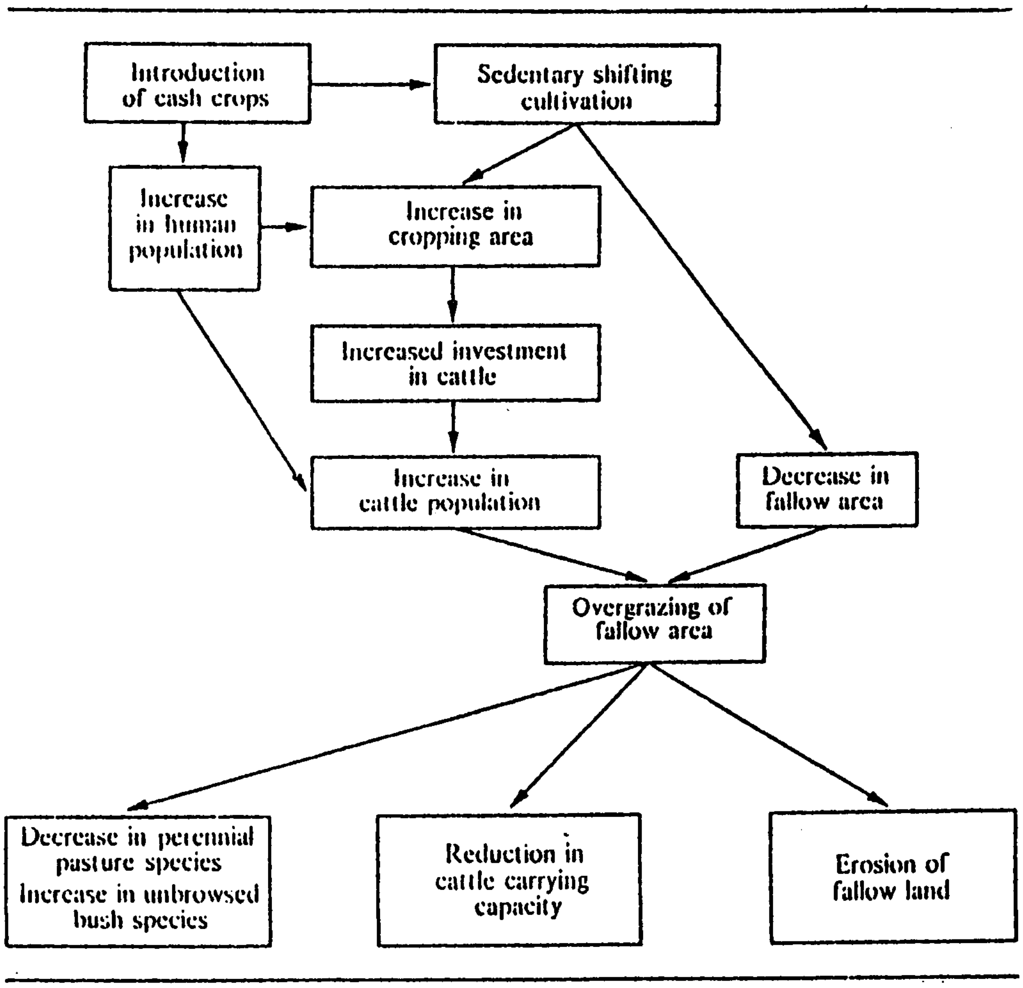


Fig. 28: Schematic representation of the degradation events in the Savana of Africa by expanded cultivation (Williamson and Payne, 1988).

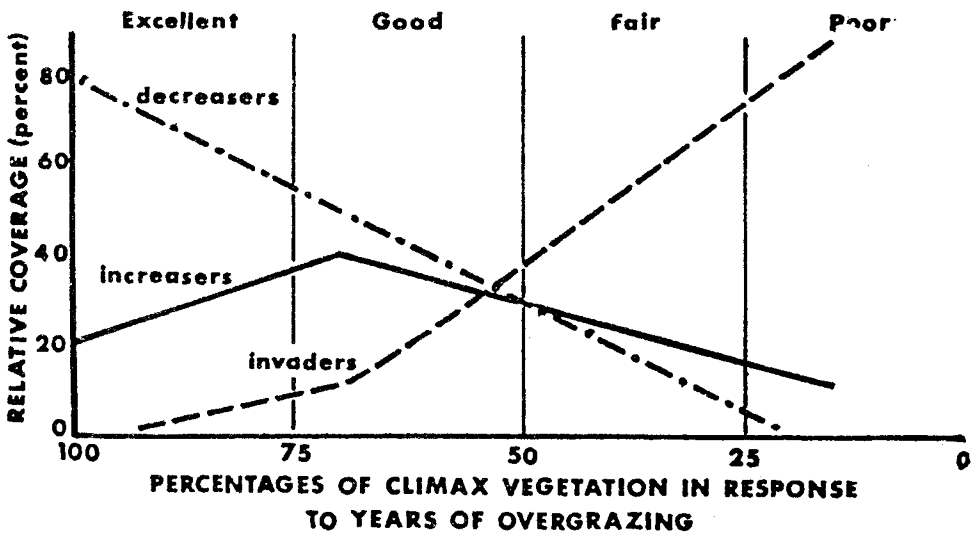


Fig. 29: Effect of overgrazing on pasture quality, adapted after Gay (1965).

management, expansion of protected areas, and sustainable management of forests". In this panel the following managerial systems of the Arid Rangeland is proposed as summarized in the following options.

Steps and management options for arid rangeland degradation.

Stepwise degradation of arid or semi-arid rangelands. Symptoms describe the state of plant and animal assemblages; management options refer to actions that a manager could take to improve the condition of the range; and management level refers to the system (level of the food chain) on which management should be focused.

Step 0	
Description:	Biomass and composition of vegetation varies with climatic cycles and stochastic events (e.g., droughts, diseases, hail, frost, fire)
Symptoms:	Perennial vegetation varies with weather
Management Option:	Adaptive management, involving timely manipulations of livestock densities; Secondary producers (i.e., grazers and herbivores)
Management Level:	
Step 1	
Description:	Herbivory reduces reestablishment of palatable plants, allowing populations of unpalatable species to grow
Symptoms:	Demography of plant population changes (age-structural changes)
Management Option:	Strict grazing controls
Management Level:	Secondary producers
Step 2	
Description:	Plant species that fail to establish are lost, as are their specialized predators and symbionts
Symptoms:	Plant and animal losses, reduced capacity to support herbivores
Management Option:	Manage vegetation (e.g., add seed, remove plants)
Management Level:	Primary producers (i.e., vegetation)
Step 3	
Description:	Biomass and productivity of vegetation fluctuates as ephemerals and weed species benefit from loss of cover from perennial plants
Symptoms:	Perennial biomass reduced (short-lived plants and instability increase), resident birds decrease, nomadic bird species
Management Option:	Manage soil cover (e.g., mulching, erosion barriers, roughen soil surface)
Management Level:	Physical environment (soil)
Step 4	
Description:	Denudation and desertification involve changes in soil function and soil microbe activity
Symptoms:	Vegetation cover completely lost, erosion accelerated; soil salinization, Aridification
Management Option:	Difficult to address; costs of restoration or rehabilitation too high; nonpastoral use of land only economic option
Management Level:	Difficult to identify

Approaches for Pasture Development

Whiteman (1980) discussed the approaches of research and application for pasture development and summarized it as in Table (14). He defined the level of intensification of pasture utilization as listed in Table (15). The levels of range management for pasture development have significant effect on livestock production as evidenced in tables (10, 11 & 12) Pasture development, however, must be realized on economic bases. Whiteman (1980) stated "There are difficulty in making generalized comparisons between production systems. Nevertheless, budgetary comparisons can be made within a particular region at a given point in time. The major variables which must be taken into account for pasture development by the two systems, 1) legume oversowing and 2) fertilization:

1. Land value: more land will be required to carry the same number of animals in a legume system than in a nitrogen fertilized system.
2. Animal costs: on a given area of land, more animals will be carried in a nitrogen fertilized system, thus increasing capital investment in animals, and veterinary costs.
3. Labor costs: probably similar if herd sizes are similar between systems.
4. Pasture establishment: legume-seed cost is additional in the legume system. Also as legume content tends to decline, resowing of legume must be budgeted after 10-15 years.
5. Fertilizer costs: maintenance requirements of phosphorus, potassium and other elements are generally applied at similar rates in the two systems. The major the cost of nitrogen in the nitrogen system.
6. Beef price: this is a major variable affecting the profitability of both systems.

Table 14. Stages of studies for pasture researches and development programmed (Whiteman, 1980)

Survey	
(i)	Define the regions within which a similar range of climate, soils, vegetation, and land use is found
(ii)	Within regions identify those with major livestock populations
(iii)	Define regional pasture and forage resources, and areas with potential for future development
(iv)	Identify limitations to livestock production in existing husbandry systems and with existing forage resources
Allocate priorities for research	
(i)	Decide appropriate levels of intensification for particular regions or land units
The pasture research and development programme	
Assessment	
(i)	Assessment of soil fertility on major soil types
(ii)	Evaluation of potentially useful grass and legume species through a Plant introduction programme
Regional testing	
(iii)	Regional testing of adapted species in grass-legume mixtures in plot with grazing
Grazing assessment	
(iv)	Selected mixtures grazed at a range of stocking rates to determine pasture persistence, optimum stocking rate arid levels of animal production
Management studies	
(v)	Longer term studies on best mixtures to determine optimum grazing management, fertilizer management, and limitations
Application	
Extension	
(i)	Extension to farmers - field days, demonstration trials, co-operative trials with landowners
(ii)	Develop pilot farms or commercial ranches
Monitoring	
(i)	Identify field problems for further research

Table 15. Levels of intensification of pasture utilization (Whiteman, 1980)

Major production system	Pasture or grazing management characteristics
Extensive rangeland grazing	*Nomadic herding.* Transhumant grazing. No pasture improvement *Sedentary grazing.* Animals herded around water points, or communal ranch blocks or on crop residues around villages *Extensive ranching.* Extensive grazing on range, with or without fencing, animals not herded
Managed rangeland	*Ranching.* Fencing, increased watering points, timber clearing, woody weed control, animal supplementation
Improved rangeland	*Oversown range.* Introduction of improved legumes or grasses, after burning or cultivation *Fertilized oversown range.* As above with inputs of fertilizer for the oversown species
Cultivated Sown pastures	Replacement of native species with sown pastures, with fertilizers, cultivation, and grazing management (i) Sown grass-legume mixtures (ii) Sown pure grass plus fertilizer nitrogen (iii) Sown pure grass plus fertilizer nitrogen plus irrigation (iv) Sown annual Special purpose pastures (e.g. annual rye grass plus nitrogen; subterranean clover pastures)
Fodder crops	Annually sown fodder crops, grazed
Zero grazing systems	Forages or fodder crops, cut, carted, and fed to animals in stalls or enclosures

Livestock Disease and Parasites Constraints (in Africa)

Disease and parasite constraints on livestock productivity are worst in Africa. Not only is a large area of the continent infested with tsetse flies, the vectors of trypanosomiasis, but there are a larger number of tick-borne diseases than elsewhere, including East Coast Fever (ECF), that only occurs in East Africa. Contagious Bovine Pleuropneumonia (CBP) is particular problem Foot and Mouth disease used to be endemic almost everywhere in Topical Africa. Calving percentages are very low in many regions and this is partially due to widespread of phosphorus and other mineral deficiencies in the forage. It may be concluded that in Africa disease and parasites are not only a major constraint on productivity in the extensive beef industry but also on the beef export trade (Williamson and Payne (1988)).

The incidence of disease and parasites with accompanying mortality will be much higher if the types of cattle used are not acclimatized to their environment. For example, de Pinho Morgado (1961) showed that in Mozambique, under the same conditions of feeding and management, indigenous Landim cattle had a lower mortality rate than introduced Africander cattle, although the latter are indigenous to Africa, and a very much lower mortality rate than introduced Herefords, the mortality rates were 4.0, 7.5 and 33.3 per cent, respectively. A further interesting observation was that the mortality of cossbred Landim x Hereford cattle, at 5.6 per cent, was lower than that of the Africander cattle. In the Equatorial Tropics young calves are very prone to pneumonia in very wet weather. Calf mortality in some areas can be so high that it is worth while considering the erection of cheap shelters on the pastures for use by breeding cows with calves afoot. Stobbs (1966) reported on attempts to introduce cattle from tick-free to non-tick-free areas in East Africa, stated that the moralities of purebred Boran, crossbred Boran x Small East African Zebu and Purebred Small East African Zebu were 77,43 and 23 per cent, respectively, despite the fact that Small East African Zebu cattle are indigenous to the non-tick-free areas. Cattle cannot be herded in tsetse-infested areas without very special precautions and/or the use of prophylactics. The use of the latter is not normally economic (Williamson and Payne (1988)).

Zebu or humped cattle (*Bos indicus*) are tolerant to drought, to heat and to tick-borne diseases (TBD) [Heartwater, anaplasmosis, babesiasis, (= redwater = piroplasmosis), east coast fever]. TBD are an important constraint to cattle husbandry in Eastern and Southern Africa but not so in West Africa, perhaps because of the very low air humidity and of the long dry in the livestock production zones (Sahel and N. Sudanian zones), although some outbreaks are known to occur every now and then in various areas such as the inland delta of the Niger River. Tick-borne diseases also used to constitute a significant constraint in N. Africa until the generalization of synthetic insecticides in the 1950s, hence the early import of Indo-Pakistani zebu breeds, e,g., Nellore, Red Sindi, Sahiwal and Brahma. Conversely, humped cattle are very sensitive to trypanosomiasis and therefore do not penetrate deep into the sub-humid zone lowlands (unless tse-tse flies have been eradicated). The upper limit of tse-tse fly distribution is about 1200 m of elevation under the equator. The upper midlands and highlands are thus free of trypanosomiasis, i.e., when the mean annual temperature is below 22 °C and the minimum below 15 °C. In the tse-tse infested zones (Fig.30) i.e., roughly above the 800mm rainfall and below 1200 m of elevation, trypano-tolerant taurine cattle (Bos taurus) such as the N'dama breed from the Fouta-Djalon (Guinea) or West African short-horns (Muturu, Baoule, Mere), the Kuri and Sanga/Ankole tend to replace the zebu in trypano-infested regions. The same phenomenon is observed in small stocks with the West African achondroplasic (i.e., dwarf) goats and sheep (Djallonke), which are ± trypano-tolerant and are the only breeds kept in the humid zones (Le Houerou et al., 1993).

Camel (dromedaries) are sensitive to diseases and parasitism (tick borne diseases as well as trypanosomiasis); for this reason they are restricted to hyper-arid, and arid (occasionally semi-arid) zones. Nowhere in Africa are they found above the 600 mm rainfall and often not beyond 400 mm (Le Houerou et al., 1993).

The overall situation would appear to be that epidemic diseases and some external parasites will continue to be difficult to control under extensive managerial conditions, but that well-planned eradication programs, improvements in vaccine production and distribution and improved nutrition and management, disease and parasites will cease to be major constraint on beef cattle productivity, except perhaps in some regions in Africa. It is of course essential that extensive holdings should have available suitable facilities, such as, well-planned and constructed yards where vaccination can take place and dip tanks or sprays for the control of external parasites. Tick-control programs must always be established. Except under exceptional conditions the complete eradication of ticks is considered unrealistic, but some form of tick control is usually needed everywhere, particularly in those regions of Africa where ECF is endemic. Mortality, even of indigenous cattle, can be very high indeed in ECF areas.

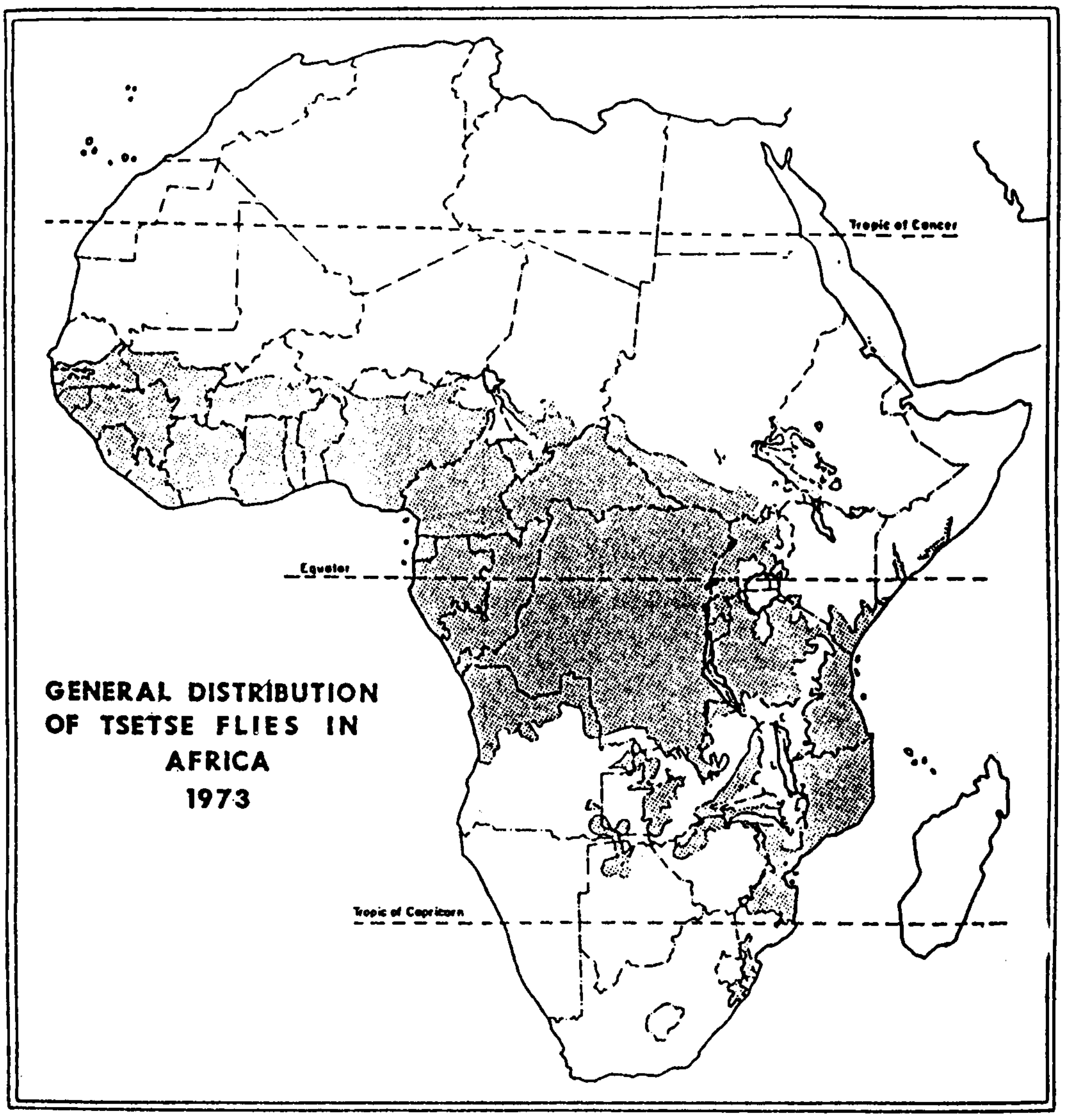


Fig. 30: African regions infested with tsetse flies (Le Houerou et al., 1993).

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